Whither the Whales

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COVER: The leaping humpback was painted especially for *Oceanus* by the versatile Cape Cod artist Sig Purwin, who is also represented in this issue with pen and ink sketches for the Voyages article, page 127.

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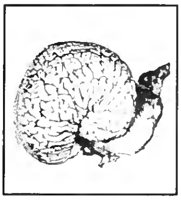

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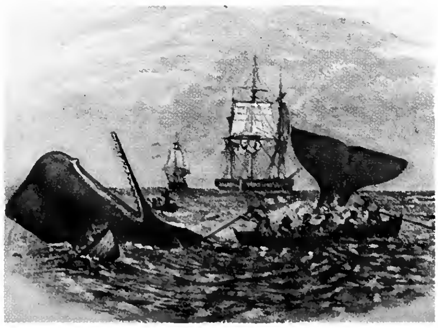
Facts & Fantasy

Not the cuddly looking pandas under threat in the vanishing bamboo forests of Szechuan, or the sloe-eyed baby harp seals clubbed to death on the Labrador ice for their soft fur, or even that ephemeral ozone "hole" over Antarctica—not any of these things, living or inanimate—have come to symbolize our heightened concern over the planet's well-being so much as the whales.

Everywhere we look we're told of their plight. They stare at us from bumper stickers and T-shirts ("Save the Whales," "Extinction is Final"). We read about them in our newspapers and magazines. Hardly a month passes without a new book or television special extolling these magnificent creatures. No doubt about it: whalemania is a growth industry. As fundraisers for environmental organizations have long known, nothing is more likely to tug at the heartstrings—or purse strings—than the sights and sounds of whales. Shopkeepers can't seem to stock enough whale models or posters, while the living kind are the star attractions of our proliferating marine parks and growing whale-watching fleet.



Woodcut of Yankee whalers hunting sperm in the South Seas. (The Bettmann Archive)

Is there another wild creature as widely adored? Or capable of unleashing such passions? Some zealous "friends" of the whales have waged a veritable war at sea, throwing themselves in front of the whaling ships as they are about to fire their harpoons, or sabotaging them at their docks. During the Reagan years, environmentalists often went eyeball to eyeball with Secretary of the Interior James Watt, who dismissed them as "tree-huggers" and worse, but saw absolutely eye to eye with him about saving the whales.

Protection of the whales remains an uncompromising part of American policy, putting us sharply at odds with otherwise friendly nations, like Japan, which happens to believe whales are a tasty source of protein. As biologist Peter Tyack says, they are our "sacred cows."

How did these animals come to insinuate themselves into our psyches? Moreover, do they deserve this enormous investment of public emotion? After all, what do we really know about them? Or about their life in the sea? Do they have the enormous capabilities that some romantics ascribe to them? Are they, in fact, as imperiled as the environmental Cassandras have suggested?

Opposite: Sometimes whales, like this humpback, seem to eye us as curiously and as anxiously as we view them. (Photo by J. Michael Williamson, Mingan Islands Cetacean Study)

In an effort to filter hard facts out of the sea of fantasy surrounding the leviathans, we are devoting this issue of *Oceanus* almost entirely to Cetacea, the order comprising the 75 or so species of aquatic mammals known as whales, porpoises, and dolphins. In the following pages, you'll find some of the latest and most informed scientific opinion about the animals that have become a national obsession. You'll also get some provocative answers to the questions we've posed.

Each of our scientist-authors is a leader in the field. Each has spent countless hours observing whales in the water and pondering them back on land. As you read about their fascinating work, you'll discover that they're cool and hard-headed—as scientists should be when they're reporting and assessing their observations.

What they say may surprise you. Or even exasperate you. They tell us, for example, that whales aren't the powerful intellects some have claimed. Some species, they add, could perhaps be safely hunted without jeopardizing their survival. Looking back upon the spectacular rescue of two gray whales locked in ice off Alaska last year, several of our writers raise questions about the value of the costly operation, even though it apparently had strong public support. (We also offer some approving voices on this subject.) Does the unsentimental attitude of those who study whales mean they're unsympathetic toward them? Of course not; otherwise they would hardly devote themselves to learning more about them.

Our current infatuation with whales represents an astonishing change in public opinion. In the 19th century, no one hunted whales more aggressively than Americans. Yankee whalers prowled the globe for the leviathans, from the Arctic to Antarctica, without moral compunctions. Whales were viewed as menacing and dangerous, perhaps evil (and also a good payday). Ahab's dark vision of the great white whale was probably not atypical of the day.

When the United States finally ceased major whaling in the 1920s, it was for economic rather than philosophical or ethical reasons. The hunt was no longer profitable.

Certainly, science has figured strongly in encouraging the new popular appreciation of whales. In recent years, researchers have confirmed the old whalers' suspicions. Whales are highly intelligent, social animals, superbly adapted to their environment. This is especially true of the toothed whales, such as the sperm, killer, and those "little whales," the dolphins. Many of their characteristics seem almost designed by evolution to endear them to humans, with our great weakness for seeing reflections of ourselves in the natural world. These whales probably communicate on a level as high as that of wolves, form strong bonds—killer whales, for instance, spend their entire lives in the same families—and nurture their young for periods that can last years.

Soviet whalers towing back catch after nine months in Antarctica in 1960s. (UPI/Bettmann Newsphotos)

But they're certainly not the "minds in the water" of legend. Despite the discredited claims of a few researchers, dolphins can't learn anything even approximating the complexity of human language. Nor does the huge brain of the sperm whale (weighing about 25 pounds in an adult) mean this animal is capable of higher thought, like composing a symphony, as some dreamers have suggested. (What that huge brain does, however, remains a mystery.) As for Cetacea's other major branch, the baleen whales, like the humpback and the bowhead, many scientists regard them as cows of the sea. But what cows! Who cannot but marvel at these "bovines" leaping mightily from the sea or displaying their great butterfly-shaped flukes.

Equally important in stirring our sympathies is the issue of the whales' survival. Once whaling was an extremely dangerous occupation; the risks were divided much more equitably between the hunter and his prey. Now the odds are entirely with the hunter, who has at his disposal high-speed ships, electronic finding techniques, and powerful cannons to fire explosive-tipped harpoons. This weaponry makes the kill astonishingly efficient. Even fast-swimming fin whales (top speed: 20 knots), which could easily elude a wind-powered whaler in the last century, no longer have a prayer—if they could say one—against the modern whaler.

In this century, perhaps as many as a million and a half whale carcasses were hauled aboard factory ships before the International Whaling Commission (IWC) called off the slaughter in 1986. (These figures don't include hundreds of thousands of dolphins trapped in fishing nets.) Populations of the great whales dwindled sharply, especially of such major species as the blue, humpback, bowhead, and right whales. Some seemed headed for extinction almost as surely as the dodo.

Under strong pressure from the United States, Britain, and other foes of whaling, the IWC was transformed from "the whaler's club," responsible for setting harvesting goals that would ensure maximum yields from the stocks, to an organization that actually voted a five-year ban on commercial whaling. Not on all whaling, to be sure; native hunters like Alaska's Inuits can still take a few whales, as can whaling nations like Japan, Norway, and Iceland under a loophole that allows whaling for "research" purposes. But the moratorium will soon end. And unless the IWC takes action, whaling may be resumed in full force in 1991.

Some of our authors aren't especially worried about a controlled hunt of certain "recovered" species. They assure us that these are renewable resources that could feed many people. Of greater concern to them are other threats. Each year thousands of dolphins are lost in the nets used by the purse-seine yellowfin tuna fishery in the eastern tropical Pacific, and even mighty sperm whales occasionally find themselves fatally ensnared in the thousands of miles of nylon left adrift in the oceans by fishermen.

There is also the serious matter of the growing destruction of habitat. Pollution and other byproducts of human activity have brought some river dolphins dangerously close to extinction. They have also raised concerns over the gray whale's breeding lagoons in Baja California, and have reduced to perilously low numbers the belugas of the St. Lawrence.

The condition of the belugas has special poignancy. Listening to the lively whistling and squealing of the little white whales through the wooden hulls of their ships, 19th-century sailors called them "sea canaries." It's an image that may still have relevance. For if the sea canaries of the St. Lawrence or, indeed, any other whales perish, we'll have to ask ourselves, as did the old miners when their canaries died: What or who goes next?

—Frederic Golden
Acting Editor, *Oceanus*

The Plight of the 'Forgotten' Whales

It's mainly smaller cetaceans that are now in peril

by Robert L. Brownell, Jr., Katherine Ralls, and William F. Perrin

The "Save the Whales" movement, the most successful wildlife crusade in history, has greatly influenced government policies in a number of countries, including the United States. Thanks in large part to the movement's dedicated members, the fight to save the great whales has been largely won. Yet all but ignored in this victory has been the plight of smaller cetaceans, which continues to worsen.

The pivotal year for the great whales was 1970, when nine of the 12 species were listed as endangered under the U.S. Endangered Species Act (ESA, box, pp. 12–13). At that time they met the ESA's definition of an endangered species (Table 1). They were overexploited by commercial whalers and inadequately protected by laws and regulations. These are now two of the five criteria that must be considered when species are listed or taken off the list under the ESA (Table 2). Although the ESA list still includes all the great whales that were originally on it, the major concerns that prompted their inclusion are no longer relevant.

This vaquita drowned in gillnets set to study the fish totoaba in the upper Gulf of California.

Some of the great whales have been completely protected by the International Whaling Commission (IWC) for many years. Now all of them are protected under the moratorium on commercial whaling implemented by the IWC in 1986. In that year, 7,200 great whales were killed,* compared to more than 55,000 in 1966. Fewer than 700 were killed in 1988, all under the research or subsistence provisions of the IWC moratorium which expires in 1991.

In marked contrast to the improving prospects for the great whales, the status of many smaller cetaceans has continued to deteriorate over the last two decades. Some species and local populations of dolphins, porpoises, and small whales are in greater danger of extinction than any of the great whales, except possibly the northern right whale, *Eubalaena glacialis*. For example, the population of the baiji, or Chinese River dolphin, *Lipotes vexillifer*, is believed to be down to only about 300 individuals. Each year hundreds of thousands of other small cetaceans are killed incidentally in various fisheries around the world. However, the situation of most of these smaller cetaceans has received relatively little public attention—indeed, they are almost forgotten species—and they receive almost no legal protection, except for the regulation of the U.S. tuna/dolphin fishery and the kill of Dall's porpoise, *Phocoenoides dalli*, in Japanese salmon gillnets. Only one small cetacean, the vaquita, or Gulf of California harbor porpoise, *Phocoena sinus*, is currently on the U.S. Endangered Species List, and it wasn't even listed until 1985.

But before we look at the small cetaceans in detail, we will briefly review the status of their larger relatives.

The Condition of the Great Whales

The northern right whales and southern right whales, *Eubalaena australis*, earned their name because they were were easy to capture and floated when dead—they were the "right" whales to hunt. They were pursued from early times in the coastal waters of temperate latitudes in both hemispheres until all populations were reduced to extremely low numbers. For about 50 years

*Most of these whales were taken by Japan, the Soviet Union, and Norway. These countries had lodged formal objections to the moratorium and so were allowed by the rules of the IWC to set their own quotas and continue whaling. Norway and the Soviet Union ceased commercial whaling in 1987, and Japan in 1988.

A female Indus river dolphin. Only 500 of this species survive. (Photo by Earl S. Herald)

Feeding goldfish to a pair of Irrawaddy dolphins in Jakarta. (Photo by Helene Marsh)

now, they have received almost complete protection in most parts of their ranges. Some populations in the southern hemisphere are beginning to increase. We believe there are about 3,000 right whales in these southern hemisphere stocks. However, there is still no evidence of population growth in the northern hemisphere stocks, which may number less than 500. Reduced along with some of the stocks of the bowhead whale, *Balaena mysticetus*, to the lowest levels of any whale populations, it may take decades before these stocks show signs of increase.

Historically, bowheads were found in virtually all Arctic waters. The commercial fishery began during the 17th century and lasted until the early part of this century. Commercial exploitation ended when the value of the bowhead's two main products—baleen and whale oil—was reduced drastically by the development of spring steel and petroleum products. Since the 1920s, the bowhead has been hunted only from about two dozen coastal villages in the United States and the Soviet eastern Arctic, and in the last decade, only by the Alaskan Inuit. The largest remaining stock of this species, about 7,800 whales, ranges throughout the Bering, Chukchi, and Beaufort Seas (article pp. 54–62).

The gray whale, *Eschrichtius robustus*, originally roamed the northern hemisphere along the coasts of both the Atlantic and Pacific Oceans. It became extinct in the North Atlantic in the 1700s, possibly because of overexploitation by Basque and American whalers, and was hunted to low numbers on both sides of the North Pacific in the last century. The eastern, or California, population has been protected by the IWC since 1946. A regulated catch of about 180 is taken each year off the Chukotka Peninsula of the Soviet Union for subsistence use. Since it was protected, the population has increased to more than 20,000 animals, which is thought to be within the range of its prewhaling level.

Protecting the Humpbacks

Humpback whales, *Megaptera novaeangliae*, are found worldwide. Their coastal migrations made them extremely vulnerable to overexploitation, and they were greatly depleted throughout the world by both land station and pelagic whaling operations. Since 1966, the IWC has protected humpbacks from commercial whaling throughout the world. A subsistence fishery off Greenland ended in 1987. Limited subsistence hunting is allowed in the Caribbean (*Oceanus*, Vol. 30, No. 4, pp. 89–93). The present world population is estimated to be more than 10,000 whales.

The blue and fin whales, *Balaenoptera musculus* and *B. physalus*, were not exploited until the invention of fast steam ships and the grenade harpoon in the second half of the 19th century. Nevertheless, the blue whale was severely depleted in the southern hemisphere to less than 10 percent of its original estimated population. The last blue whales taken in the southern hemisphere were caught in 1967. Although they have been totally protected for more than 20 years by the IWC, there has been no detectable increase in numbers over that period. In the northern hemisphere, however, groups of blue whales are commonly seen in the waters off Sri Lanka, California, and Baja California, and in the Gulf of St. Lawrence. The worldwide population is currently less than 10,000 individuals.

After the decline of the blue whales, the fin whale constituted the major portion of the world's catch of whales. More than 100,000 fin whales were taken during the 1960s alone. As a result, some populations were depleted, especially those in the southern hemisphere. The remaining southern hemisphere fin whales have been protected by the IWC since the early 1970s,

Robert L. Brownell, Jr., Katherine Ralls, and William F. Perrin are research scientists with the U.S. Fish and Wildlife Service, the Smithsonian Institution, and NOAA Fisheries, respectively. (All photos in this article are by Brownell unless otherwise noted.)

but catches continued in the North Pacific until 1975, and a small research catch is still allowed under special permit each year by Iceland in its waters (article, pp. 29-36). Last year Iceland caught 68 fin whales. The present worldwide population estimate is imprecise, but is on the order of 150,000 animals.

During the 1960s, following the fin whale's decline, sei whales, *B. borealis*, were heavily exploited in the southern hemisphere. These large catches—22,205 whales landed in 1965 alone—greatly reduced this last species of large whale in the area. Smaller catches of sei whales occurred in the North Pacific and North Atlantic throughout most of the 20th century. The IWC has protected the North Pacific stocks since 1976, and had protected all North Atlantic stocks prior to the 1986 commercial whaling moratorium. A rough worldwide estimate is at least 50,000 whales.

Bryde's whale, *B. edeni*, usually lives in tropical and subtropical waters, but sometimes visits cooler areas. This species has not been of major importance in commercial pelagic whaling, but has been taken in the coastal waters of the western Pacific, and off Brazil, Peru, and South Africa. Catch records are confusing because of the difficulty of distinguishing Bryde's whale from sei whales.

The minke whale, *B. acutorostrata*, is the smallest of the great whales. Although various coastal countries in the northern hemisphere have captured minke whales for much of the last 50 years, commercial exploitation by pelagic whaling operations in the Antarctic did not begin until the early 1970s, and ceased after Japan's 1986/87 season. The southern hemisphere populations are currently estimated to be more than a half million individuals. Japan began some low-level research catches of about 300 whales a year in the Antarctic in 1988. The only minke whales taken in the northern hemisphere during 1988 were 30 for research by Norway, and about 110 off Greenland for subsistence.

Little is known about the pygmy right whale, *Caperea marginata*, that occurs in temperate waters of the southern hemisphere, since few specimens have ever been examined by scientists and it has never been exploited commercially. Even sightings at sea are rare.

Sperm whales (usually known as *Physeter catodon*, but also referred to as *P. macrocephalus*) are found in all the oceans, from the equator to the polar seas. They have been the subject of two major phases of whaling: "old" whaling, mainly from the mid-18th to mid-19th centuries; and "modern" whaling, particularly between 1946 and 1980. Catches were taken by pelagic and coastal operations. During the latter phase most catches were taken in the North Pacific. In 1966, the world catch was more than 27,000 whales. The fishery concentrated on large males in many areas, and much of the recent concern of scientists has centered on possible effects of this selective removal on reproductive rates. All commercial whaling on this species has now stopped, but subsistence or traditional whaling continues in some areas, such as Indonesia and the Azores. Although some local stocks are still considered depleted by the IWC, other stocks contain tens of thousands of whales.

Status of Some Small Cetaceans

While long-term protection of the great whales has allowed populations to begin to recover, or at least stabilize, the situation for many small cetaceans is bleak. Overhunting and destruction of habitats have brought various populations to dangerously low levels, yet only one species is listed as endangered under the ESA.

The vaquita, or Gulf of California harbor porpoise, an endemic species known only from the upper third or so of the Gulf of California, Mexico, was listed in 1985 by the National Marine Fisheries Service, an arm of the National Oceanic and Atmospheric Administration (NOAA). This species was first described in 1958 from specimens that were probably captured incidentally in a gillnet fishery for totoaba, a large fish. The Mexican government closed the totoaba fishery in 1975 because the fish population had declined dramatically. Closure of this fishery

Table 1. Terms to describe the status of cetaceans.

U.S. List of Threatened and Endangered Species

Endangered: Any species which is in danger of extinction throughout all or a significant portion of its range.

Threatened: Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

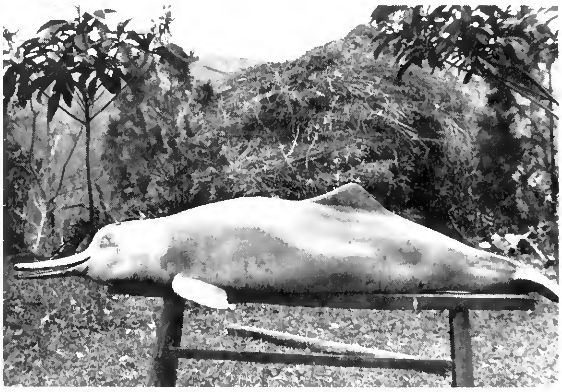
IUCN (International Union for the Conservation of Nature and Natural Resources) Red List

Endangered: In danger of extinction, survival unlikely if causal factors continue operating. Includes taxa whose members have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction.

Vulnerable: Taxa believed likely to move into the endangered category in the near future if the causal factors continue operating. Included are taxa of which most or all of the populations are decreasing because of overexploitation, extensive destruction of habitat, or other environmental disturbance; taxa with populations that have been seriously depleted and whose ultimate security has not been assured and taxa with populations that are still abundant but are under threat from severe adverse factors throughout their range.

Insufficiently known: Taxa that are suspected but not definitely known to belong to any of the above categories, because of lack of information.

Dall's porpoise, found only in the North Pacific.



The baiji, probably the world's most endangered cetacean. (Photo by Clifford H. Pope)

reduced the incidental mortality of porpoises, but other fishery operations continued to catch some vaquitas. The Mexican government has unfortunately allowed research catches of totoaba since 1985, and recently many vaquitas have been taken incidental to these fishing operations. While little is known about the biology and present population levels of this porpoise, it must be considered endangered.

Several species of river dolphins deserve special attention. Although none are listed by the ESA, two species are listed as "endangered" on the Red List of Threatened Animals published by the International Union for the Conservation of Nature and Natural Resources (IUCN), located in Gland, Switzerland.

The baiji is probably the most endangered of all cetaceans. Only a few hundred remain in the Yangtze River and their numbers appear to be decreasing. The baiji no longer occurs in many areas where it was found 70 years ago, when it was first scientifically described. A major cause of mortality is entanglement in bottom longlines equipped with fishhooks every few centimeters. This "rolling hook" fishing gear happens to be laid in regions with the highest baiji densities. Although China has declared the species a "Protected Animal of the First Order," significant numbers continue to be killed incidentally by such human activities as fisheries, boat traffic, and explosions from construction work. The Chinese have proposed two seminatural reserves for the baiji; the consensus of scientists attending a recent workshop in China on river dolphins was that work should begin on both reserves as quickly as possible.

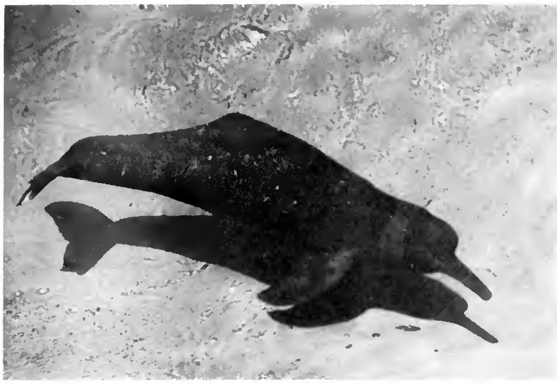
The Indus river dolphin, *Platanista minor*, is also in danger, with a total world population of about 500 individuals. More than 400 are protected in a reserve, but the remaining animals are divided into four isolated and unprotected populations in the Punjab of Pakistan. Many populations in the Punjab have already disappeared, and surveys indicate that the remaining populations outside the reserve are declining rapidly.

Although not as critically endangered as the Chinese and Indus river dolphins, other species of river dolphins are of concern. Populations of the Ganges river dolphin, *Platanista gangetica*, seem to be declining due to human activities in India, Bangladesh, and Nepal, and rapid development in the Amazon River basin is resulting in the loss of essential habitat for the boto, or Amazon river dolphin, *Inia geoffrensis*, and the tucuxi, *Sotalia fluviatilis*. Incidental gillnet mortality of tens of thousands of franciscanas, *Pontoporia blainvillei*, over the last 40 years off southern Brazil, Uruguay, and northern Argentina may have had a significant impact on this species.

Hector's dolphin, *Cephalorhyncus hectori*, inhabits the coastal waters of New Zealand. The total population may consist of only a few thousand individuals. In recent years, Hector's dolphins have been caught incidentally in gillnet fishing operations. Some scientists believe that the population has been significantly reduced. This species is highly vulnerable because of its relatively small population size, coastal habitat, and continuing incidental mortality that may exceed net recruitment in all or part of the species' range.

There may be tens of millions of spinner dolphins, *Stenella longirostris* and *S. clymene*, throughout the tropical waters of the world, but some local populations are declining. A morphologically distinct population known as the "eastern spinner" has been greatly reduced in the eastern tropical Pacific Ocean. Incidental catches of this population in the tuna purse-seine fishery have reduced it to about 20 percent of its original size over the last two decades—declining from about 2,000,000 to 400,000. Although the population is protected by the U.S. government under the Marine Mammal Protection Act (MMPA), U.S. fishermen are allowed to kill 2,750 per year, and many more are killed each year by non-U.S. tuna boats operating in the eastern tropical Pacific.

A hand harpoon fishery for Dall's porpoise in Japanese waters landed between 5,000 and



The boto, a South American river dolphin, is threatened by development of the Amazon basin.

9,000 animals annually during the 1960s and '70s. In recent years this fishery has expanded to meet the increased demand for porpoise meat. The annual catch is now between 10,000 and 13,000 individuals. This catch is 10 percent or more of the total number of Dall's porpoises—about 100,000 individuals—known to migrate through the fishing ground. Tomio Miyashita and Toshio Kasuya of the Far Seas Fisheries Research Laboratory in Japan are concerned, as are we, that the continuation of the harpoon fishery at such high levels will further deplete Dall's porpoise populations. An unknown but presumably large number of porpoises is also caught incidental to Japanese, Taiwanese, and Korean drift-gillnet fisheries for salmon and squid in the North Pacific.

The number of endangered cetacean populations continues to grow as more data are collected, yet these species have seldom been given adequate recognition or protection. Some additional populations at risk are listed in Table 3.

A Strategy for Cetacean Conservation

We propose a three-part strategy for cetacean conservation as follows:

EVALUATE THE STATUS OF ALL SPECIES

For the last 25 years, conservation biologists have described the status of the world's biota by compiling lists that have included only those species definitely known to be in trouble. Christoph Imboden, Director of the International Council for Bird Preservation in Cambridge, England, has pointed out that this strategy was a major error, because many people have assumed that any species not included on these lists is in no danger.

This assumption is false. Conservation biologist Jared M. Diamond, of the University of California at Los Angeles, has summarized recent surveys of birds and bats on tropical islands. His summary reveals that many species never included on endangered species lists because of insufficient data are now extinct. Because there are so many other species whose present status is unknown, but that may be endangered, Imboden and Diamond suggest that conservationists should also compile "Green Lists" (in contrast to the IUCN's Red List) that include only those species in no danger of extinction.

For cetaceans, we suggest a Green List of those species and populations known to be secure, a Red List of those known to be threatened or endangered, and a Gray List of those that may be threatened or endangered but whose true status is unknown. Margaret Klinowska (article, pp. 19–20) of Cambridge University is working on a new IUCN Red Data Book for cetaceans. It will evaluate the status of each species, rather than just those the IUCN currently recognizes as endangered, vulnerable, or insufficiently known.

REVISE ENDANGERED SPECIES LISTS

The present U.S. Threatened and Endangered Species List under the ESA lacks international scientific and political credibility with respect to cetaceans. It includes some species that are in no danger, and fails to include others that are nearly extinct or severely threatened. Revising this list to reflect the actual status of the world's cetaceans would make it a more valuable conservation tool.

Species of whales with large and increasing populations that are no longer commercially exploited are not endangered according to the present definition of "endangered" under the ESA or any other reasonable definition of the word. Some cetaceans listed as endangered, such as the sperm whale and the California gray whale population, do not even meet the less stringent criterion for "threatened" status.

The present status of the great whales is more accurately reflected by the Red List maintained by the IUCN. It now lists only four of the great whales as endangered in its Red List: the blue, bowhead, northern right, and humpback whales. The IUCN also lists the fin and the southern right whales as "vulnerable," a

Table 2. Criteria for listing a species (or population) as "threatened" or "endangered" under the U.S. Endangered Species Act. Only one criterion need apply for a species to be listed in either category.

1. The present or threatened destruction, modification, or curtailment of habitat or range.
2. Overutilization for commercial, recreational, scientific, or educational purposes.
3. Disease or predation.
4. Inadequacy of existing regulatory mechanisms.
5. Other natural or manmade factors affecting its continued existence.

Uruguayan fishermen set gillnets for sharks, but many porpoises and seals become accidentally entangled in the nets. The franciscanas being carried off at right may wind up as pig food or be rendered for oil.

category similar to the threatened category in the U.S. system; it does not list the gray, sperm, or sei whales in either category. However, the IUCN system also has some shortcomings, particularly in failing to recognize and classify threatened populations of species that are not threatened as a whole. Some of these threatened populations are identified in the Cetacean Action Plan recently developed by the Cetacean Specialist Group of the IUCN's Species Survival Commission. This action plan could be used as a starting point for updating the IUCN list.

We believe it is past time to reassess both the Red List and the U.S. Endangered Species List. We recommend that the U.S. government and the nongovernmental conservation organizations recognize the conservation victories that have been achieved for the sperm whale and the California gray whale population by supporting their removal from the ESA List. (The Korean gray whale population, of course, should be listed as endangered.) We also recommend an in-depth review of the present status of the other large whale populations with respect to the listing factors specified under the ESA. Such a review might result in additional species, such as the fin and sei whales, being delisted or downgraded from the endangered to the threatened category.

The delisting of no-longer-threatened species or populations would help focus attention on those great whales whose populations are still at critically low levels, such as the two species of right whales and most bowhead whale populations. Delisted species would still retain adequate legal protection under the Convention on International Trade in Endangered Species, which prohibits all trade in products derived from cetaceans. In addition, all cetacean populations in U.S. waters would still be protected by the MMPA.

Some conservationists oppose delisting any of the great whales. They argue that although these species are no longer threatened by the factors that led to their original listing, present human activities may threaten them in the future. They fear that someday the IWC may allow the resumption of commercial whaling on some species or stocks and that the oil and gas exploration now under way at many locations along the world's continental shelves could seriously harm whales that use these coastal areas. However, these possible threats are not sufficient to justify listing a species according to the factors that must be considered under the ESA. If they were, the majority of the world's animals would have to be included on the list—vast numbers of species are potentially threatened by the explosive growth of human populations, current rates of habitat destruction, and other harmful activities.

In addition to delisting nonendangered species, it is imperative to list truly endangered species. Among the small cetaceans, highest priority should be given to the baiji. A petition to add this species is already under review by NOAA Fisheries. Another species being reviewed by NOAA Fisheries, the Indus river dolphin, also deserves listing, as does the "eastern spinner" dolphin population. Listing these small cetaceans could provide the stimulus for the U.S. government to enter into bilateral agreements, under the ESA and the MMPA, for research and conservation in waters outside U.S. jurisdiction. Amendments to the Foreign Assistance Act in 1983 and 1986 require the U.S. government to support financially the conservation of endangered species and their habitats through the Agency for International Development.

Many other species and/or populations of small cetaceans may be in trouble, but insufficient data are available to support a petition to list them. The species that the IUCN includes in its "insufficiently known" category are the franciscana, the Irrawaddy dolphin (*Orcaella brevirostris*), the beluga (*Delphinapterus leucas*), the narwhal (*Monodon monoceros*), the harbor porpoise (*Phocoena phocoena*), the black dolphin (*Cephalorhynchus eutropia*), Commerson's dolphin (*C. commersonii*), Heaviside's dolphin (*C. heavisidii*), and Hector's

dolphin. These animals should be studied and listed if sufficient data become available. As more small cetaceans are listed, their true status will be better understood by both government managers and nongovernmental conservation organizations.

REFOCUS CONSERVATION EFFORTS
Because many people are unaware of the true status of various cetacean species and populations present conservation efforts are not focused on the species most in need of help. Those people who are more informed about the actual status of cetaceans should strive to inform and educate government agencies, nongovernmental conservation organizations, and the general public. Once people are aware of the true threats, they can work together to initiate international research projects on the population trends and habitat needs of each species. The Cetacean Action Plan, for instance, lists specific needs for various species and populations.

Increased Credibility

Although many people throughout the world support the conservation of whales, dolphins, and porpoises, the energy and funds available for this purpose are in short supply relative to need. Adoption of the three-part strategy we have presented should lead to better use of these limited resources by enhancing the credibility of the available data and lists, and the corresponding recommendations for the conservation of cetaceans. This strategy will also help to concentrate efforts where they are most needed. □

Commerson's dolphin, found only in the waters off the southern part of South America.

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Table 3. Populations at risk (within species not threatened as a whole), based on the recent IUCN action plan for cetaceans.

Species	Location of Population(s)
Dall's porpoise, *Phocoenoides dalli*	**Northern Japanese waters**
Burmeister's porpoise, *Phocoena spinipinnis*	**Peruvian waters**
Dusky dolphin, *Lagenorhynchus obscurus*	**Peruvian waters**
Peale's dolphin, *Lagenorhynchus australis*	**Chilean and Argentine waters**
Finless porpoise, *Neophocaena phocaenoides*	**Yangtze River and Chinese coasts**
Atlantic humpbacked dolphin, *Sousa teuszii*	**West African coasts**
Bottlenose dolphin, *Tursiops truncatus*	**Black Sea**
Common dolphin, *Delphinus delphis*	**Black Sea**
Spinner dolphin, *Stenella longirostris*	**Sri Lankan coasts, Indian Ocean, and eastern tropical Pacific**
Risso's dolphin, *Grampus griseus*	**Sri Lankan coasts, Indian Ocean**
Pantropical spotted dolphin, *Stenella spp.*	**Sri Lankan coasts, Indian Ocean**
Striped dolphin, *Stenella coeruleoalba*	**Sri Lankan coasts, Indian Ocean**
Long-finned pilot whale, *Globicephala melas*	**Waters around the Faroe Islands**
Indio-Pacific humpbacked dolphin, *Sousa chinensis*	**All populations**
Short-finned pilot whale, *Globicephala macrorhynchus*	**Northern Japanese waters**
Baird's beaked whale, *Berardius bairdii*	**Northern Japanese waters**

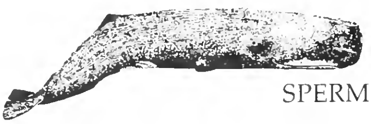
Know Your Whales: Their Names

BLUE

FIN

SEI

BOWHEAD



SPERM

NORTHERN RIGHT

SOUTHERN RIGHT

HUMPBACK

Common Name	Scientific Name	Derivation
		All derivations from Latin, except those marked (Gk) = Greek, and (ME) = Middle English.
Blue	*Balaenoptera musculus*	*balaena* = whale, *pteron* = wing or fin, *mus* = mouse[a]
Fin	*Balaenoptera physalus*	*physalos* (Gk) = rorqual whale
Sei	*Balaenoptera borealis*	*boreal* = northern
Bowhead	*Balaena mysticetus*	*mystakous* = moustache, *cetus* = whale
Sperm	*Physeter catodon*, or *P. macrocephalus*	*physeter* (Gk) = blower, *kata* (Gk) = inferior, *odontos* (Gk) = tooth, *makros* (Gk) = long, *kephale* (Gk) = head
Northern right	*Eubalaena glacialis*	*eu* = right or true, *glacialis* = icy or frozen
Southern right	*Eubalaena australis*	*australis* = southern
Humpback	*Megaptera novaeangliae*	*megas* = large, *novus* = new, *angliae* (ME) = English
Gray	*Eschrichtius robustus*	*Eschricht* = a 19th-century zoologist, *robustus* = oaken or strong
Bryde's	*Balaenoptera edeni*	*Eden* = a 19th-century British Commander
Minke	*Balaenoptera acutorostrata*	*acutus* = sharp or pointed, *rostrum* = beak or snout
Killer	*Orcinus orca*	*orcynus* = a kind of tuna, *orca* = a kind of whale
Pygmy right	*Caperea marginata*	*caperea* = to wrinkle, *marginata* = to enclose with a border
Narwhal	*Monodon monoceros*	*monos* = one or single, *oden* = tooth, *keros* (Gk) = horn
Beluga	*Delphinapterus leucas*	*delphinos* (Gk) = dolphin, *a-* = without, *pteron* = fin, *leukos* (Gk) = white

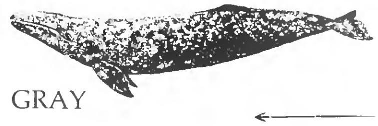
[a] Probably named in jest. *Musculus* is actually the diminutive form of mouse.
[b] Including a well-established estimate of 7,000 in the northern hemisphere.
[c] Estimate is well established.

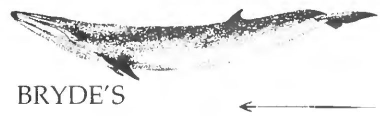
Illustrations by E. Paul Oberlander

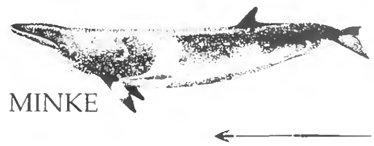
Population Estimates, and Status

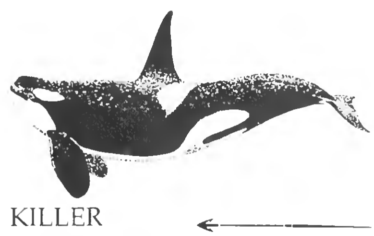
Population Estimate		Status Listing	
Pre-exploitation	**Present**	**United States Government**	**International Union for the Conservation of Nature**
All estimates are from the International Whaling Commission, and except those noted, are highly speculative.			
228,000	14,000	Endangered	Endangered
548,000	120,000	Endangered	Vulnerable
256,000	54,000	Endangered	Not listed
30,000	7,800	Endangered	Endangered
2,400,000	1,950,000	Endangered	Not listed
No estimate	1,000	Endangered	Endangered
100,000	3,000	Endangered	Vulnerable
115,000	10,000[b]	Endangered	Endangered
More than 20,000	21,000[c]	Endangered	Not listed
100,000	90,000	Not listed	Not listed
140,000	725,000[d]	Not listed	Not listed
No estimate	No estimate	Not listed	Not listed
No estimate	No estimate	Not listed	Not listed
No estimate	35,000	Not listed	Insufficiently known
No estimate	50,000	Not listed	Insufficiently known

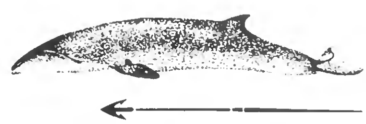
[d]Including well-established estimate of 600,000 in southern hemisphere.


GRAY


BRYDE'S


MINKE


KILLER


PYGMY RIGHT

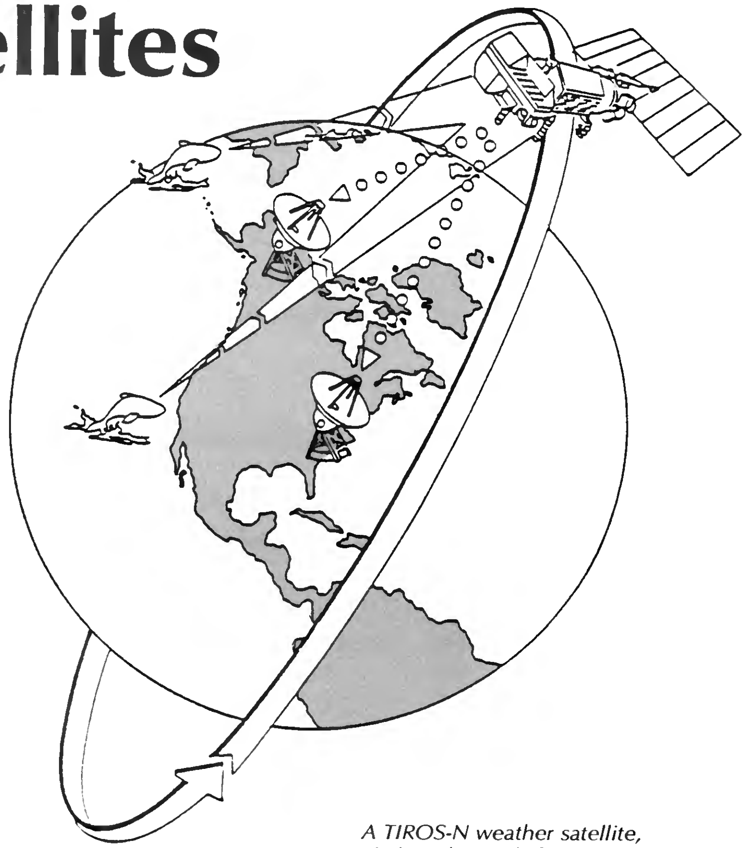

NARWHAL


BELUGA

The harpoon in each drawing represents five meters.

Watching Habits and Habitats from Earth Satellites

by Bruce R. Mate



A TIROS-N weather satellite, circling the Earth from pole to pole, receives signals from two whales equipped with Argos transmitters and relays them to ground stations, which in turn make them available to scientists.

It has often been said that "when your only tool is a hammer, you view every problem as a nail," and until very recently, whale biologists depended heavily on whaling as one of their only "tools." This left the biologist to study only those aspects of whales that could be gleaned from the flensing decks of whaling vessels. Even today, the "best guess" distribution of many highly endangered whales comes from historic catch records. Because the sea is largely opaque and generally hostile to man, identifying individual animals and observing them over long periods of time has never been easy. But now, satellites are becoming important new tools to describe the habits and critical habitats of endangered whales; and soon, information beamed up from whales may even be used to help solve some long-standing problems in physical oceanography.

A century ago, biologists knew as much about the natural history of land mammals as we know about whales today. Economic incentives back then compelled whalers to sharpen their observational skills, enabling them to decide which species could be more easily hunted and where they might find them. In the 1850s, Captain Charles Scammon identified Alaskan Eskimo harpoons in the flesh of migrant gray whales, *Eschrichtius robustus*, along the California coast, and concluded that the Alaskan population moved south in the winter to the Mexican calving areas. Large baleen whales typically migrate from high-latitude summer feeding areas to more temperate winter calving areas. The seasonal dependence of each whale species on certain geographic areas, known as critical habitats, led to the depletion of specific whale stocks, reproductively isolated populations within a species. Slow-moving coastal species such as the right whale, *Eubalaena glacialis*, were the first to be depleted. But as whaling continued to be commercially profitable, innovations eventually allowed the whaling industry to catch the

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faster species, even in such remote areas as the Antarctic (*Oceanus*, Vol. 31, No. 2, pp. 64–70).

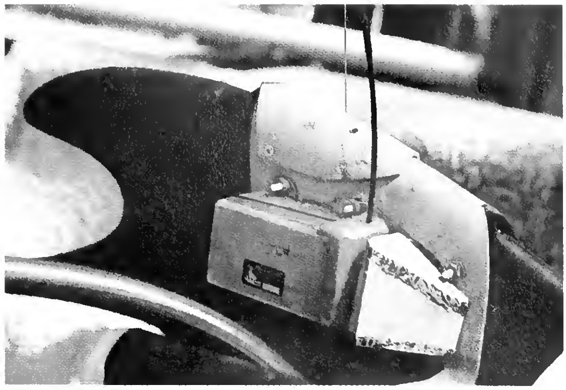
Hunting implements were the first "tags" used to discern the movements of whale stocks. By the 1930s, numbered shafts, known as Discovery tags,* were purposefully shot into whales and recovered during the commercial harvest. Despite low recovery rates, this process continued until very recently, and was responsible for identifying the movements of many whale species between feeding and reproductive areas. Knowledge of how whale stocks moved provided a basis for more "enlightened" whale management.

During the last two decades, many dedicated scientists devoted long hours to radio-tracking, and photographically identifying, individual whales in the wild. By comparing photographs from many areas, photo-ID studies provided mark-recapture population estimates, birthing intervals, and identified where individuals from specific feeding areas go to breed (article, pp. 37–44). Tracking whales with radio transmitters was pioneered in the 1960s by William E. Schevill and William A. Watkins of the Woods Hole Oceanographic Institution. The technology has since matured and resulted in numerous short-term studies of humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*), gray, and minke (*B. acutorostrata*) whales by a variety of investigators. Still, conventional telemetry has a problem: it uses low-powered transmitters that can only be heard over short distances. With the exception of monitoring migrant gray whales near shore, investigators have been compelled to rely on ships and aircraft to keep within range of the weak transmitters, and the cost has precluded long-term studies.

The Argos System

In the 1970s, the Nimbus satellite system was developed for oceanographers and meteorologists to track drifting buoys and high-altitude balloons. Today, the system has been refined and is known as Argos. Argos is primarily used for environmental studies, ranging from monitoring river water levels and seismic events in remote locations, to tracking wildlife. It is the only satellite-based location system presently available to civilians that can locate specialized transmitters anywhere in the world. The system is composed of three basic parts: transmitters, satellite-based receivers, and ground processing.

Argos transmitters send a one-watt signal on an ultra-high frequency and are extremely stable in frequency. Locations are determined from the Doppler, or frequency, shift as the satellite speeds past the transmitter. Each transmitter sends a discrete identification code and up to 256 bits of encoded sensor data during a signal



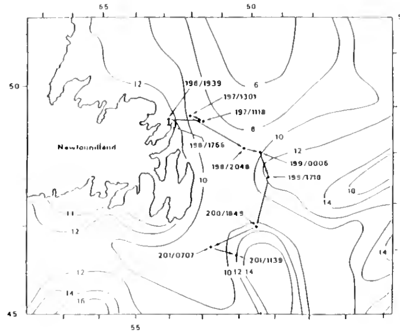
This pilot whale carries a small radio transmitter that broadcasts for three months. (Photo by the author)

lasting from 320 to 980 milliseconds. Transmissions are spaced at least 40 seconds apart so many transmitters can operate without saturating the receiver system. The messages cannot go through seawater, so whale transmitters use a saltwater switch to initiate transmissions only when the whale is at the surface. To further conserve power, the transmitters are also programmed to transmit only during times when the satellites are overhead.

There are four Argos receivers onboard each National Oceanic and Atmospheric Administration TIROS-N weather satellite. They travel in orbits 830 to 870 kilometers above the Earth, taking 101 minutes for each circumnavigation. At this altitude and speed an observer on Earth would "see" them go from one horizon to the other in eight to 15 minutes. Each TIROS-N satellite passes over both poles during each orbit, in a plane that remains at a constant angle to the sun. This effectively results in the Earth rotating beneath each satellite, making global coverage possible. Since the Earth rotates faster

Pilot whales that were released by the New England Aquarium for tracking. (Photo by the author)

*Discovery tags were so called because biologists on the Antarctic *Discovery* voyages of 1932 to 1934 used them to track whales.



In the first successful satellite whale-tracking experiment, a radio-tagged humpback was followed for six days in 1983, starting at station 196/1939. At left, a tagged female gray and her calf.

at low latitudes, the tropics receive less coverage than temperate or polar zones. Two of the Argos-equipped satellites are active at all times and can pick up messages across 5,000-kilometer swaths as they speed along their tracks.

Information received by the satellites is stored on board and transmitted to Earth when the satellite passes over one of three ground telemetry stations at Lannion, France; Wallops Island, Virginia; or Gilmore Creek, Alaska. The system has a capacity to receive information from 1,000 transmitters in the North Atlantic alone. While there are already 600 transmitters in this area associated with data buoys and so on, plans are under way to expand Argos' capacity. The satellite also immediately retransmits received data, and can be monitored by a specialized receiver known as a local user terminal (LUT). The LUT can also calculate transmitter locations, but only when the satellite is simultaneously within range of a transmitter-equipped whale and the LUT.

Information received by the ground stations is sent by other satellites to the Argos Data Processing Centers in Suitland, Maryland, and Toulouse, France, and is usually available by computer and modem link within a few hours.

While visual and conventional telemetry methods can track only one whale at a time and require on-site observers, hundreds of satellite-monitored whales can be tracked simultaneously day or night throughout the world without any ongoing field logistics or on-site personnel. However, some level of visual observation will probably always be important to understand the actual behaviors that produce the monitored diving patterns.

Successfully Tracking Cetaceans by Satellite

There were unsuccessful attempts to track porpoises by satellite during the 1970s. The first success in tracking a whale with Argos was in 1983, when a humpback whale was tracked off Newfoundland for six days, during which it travelled 700 kilometers. During the large tag's short operational life, the whale moved from an inshore area to the convergence of the Gulf Stream and Labrador currents where capelin aggregate to spawn. The use of such areas by whales is well documented, but we don't know how the whales find them. Perhaps they "remember" good places to find food, or sense oceanographic factors such as thermal fronts that attract prey, or maybe they hear other whales signaling their success at finding food.

Recently, Argos transmitters have become more energy-efficient, and small enough for successful application to small cetaceans. In 1986, three pilot whales, *Globicephala melas*, were stranded along Cape Cod. They were nursed back to health at the New England Aquarium and released in June 1987, a hundred kilometers off Cape Cod in the North Atlantic. One three-meter whale carried a Telonics-built Argos transmitter attached to a dorsal fin saddle and another was fitted with a conventional radio tag. (Telonics is the largest manufacturer of conventional and satellite transmitters for wildlife.) The staff of the aquarium was hoping that their pilot whales would survive and be accepted into a pod of their own species. The tags were applied to help them learn if their efforts were successful.

The satellite-monitored whale was tracked by Argos for 95 days, as the whale swam at least 7,600 kilometers. Just three weeks after tagging, this Argos-equipped whale was spotted in a group of more than 100 pilot whales, suggesting that its movements and dive patterns were typical of normal pilot whales. The radio beacon of the other tagged whale was also heard in the same area, confirming that at least two of the three whales stayed together. Argos monitoring and aerial observation affirmed the aquarium staff's hopes, and the long-term satellite track gave assurance of the whale's continued good health.

Never before had such insight into the long-term movements of a free-ranging whale been obtained. An average of nearly five locations were determined daily, showing that the whale swam an average of 80 kilometers a

day, or 3.3 kilometers an hour. The actual distance covered may have been two or three times the measured point-to-point distances, however, if the whale zigzagged much between the identified locations.

While most radio tags merely send a "beep beep" signal that can be located by a nearby observer, the satellite-monitored tags counted and measured every one of more than 187,000 dives without any local observer. The pilot whale performed dives lasting from six seconds to more than nine minutes throughout the day and night. The long nocturnal dives were much deeper than the long daytime dives, because temperature information from the tag showed that the whale was diving past the thermocline.* The long night-time dives were probably associated with feeding on the pilot whales' favorite food, short-finned squid. Many squid migrate vertically with the deep-scattering layer** and come up toward the surface at night. Although not always rising all the way to the surface, at night the squid are shallow enough for pilot whales to dive and feed on them efficiently. The indications of the daytime dives being shallow support observations in daylight of pilot whales feeding on schooling fishes such as mackerel. These diurnal dive differences would have been difficult to determine by almost any other means. The ecological adage, "There's no free lunch," is true, but it appears that midnight snacks may be a bargain.

From Physiology to Physical Oceanography

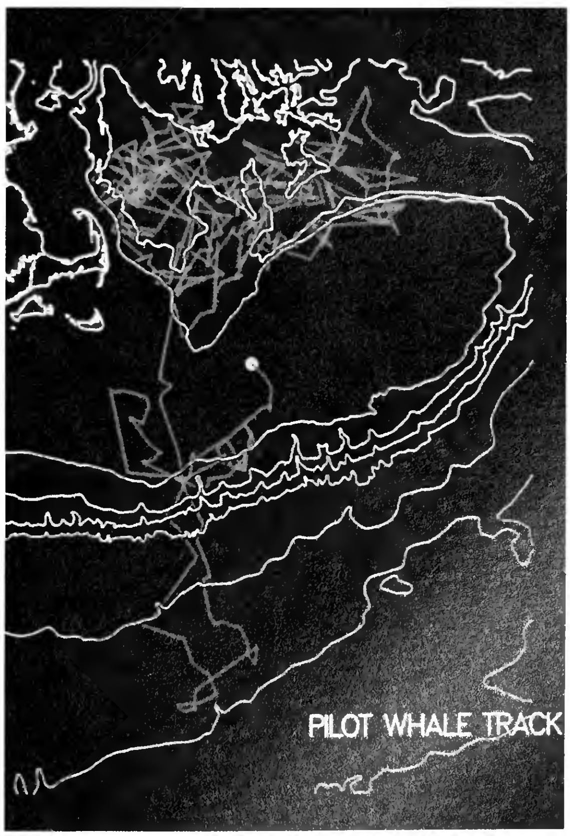
Satellite monitoring promises to shed light on the differences in individual behavior on a day-to-day basis. Until high-tech methods of monitoring whale activity came into use, even such basic information as sleeping patterns was largely unknown. Whales in captivity and in the wild have been observed sleeping at the surface, but little is known of its regularity in the wild. The satellite-monitored pilot whale revealed a pattern of sleeping at the surface every four to seven days, rather than a daily pattern like that of humans. Most typically, the whale would rest at the surface immediately after sunrise.

These glimpses into the whale's world have stimulated the development of new sensors and speculation about future transmitters that could provide a more detailed description of the whale's world. Tags currently being developed at Oregon State University will provide temperature and depth profiles of each animal's dives, and show us how whales utilize thermoclines, currents and temperatures for locating and capturing prey.

Imagine monitoring gray whales from the comfort of a warm—and dry—office, and knowing when they dive to the bottom of the Bering Sea to feed on benthic amphipods! Remotely distinguishing foraging behaviors would determine how much of a gray whale's summer activity budget is spent feeding to get ready for the three- to five-month winter fast throughout the migration and breeding season. Since females are the first to leave the feeding grounds, and the last to arrive, they must be prodigiously efficient feeders if they are to be successful in gestation and lactation. And where will it go from there? Onboard fast-Fourier analysis of vocalizations could distinguish social from echolocation sounds, giving futher information on feeding and social behaviors in addition to simply charting the whales' increasingly noisy environment. Acoustically monitoring physiological functions such as heart rate would give insights into diving physiology. While many academically interesting variations can be listed, I would hope that initially we

*A layer of water where the temperature decreases very rapidly with increasing depth.

**A broad area of sound reflection that migrates up to a depth of less than a hundred meters at dusk and down to several hundreds of meters at dawn. The migration has been linked to the movement of euphausids, fish, and squid, and can take place at a rate of five meters a minute.



The pilot whale in the 1987 Argos experiment left this track in 4,500 miles of wanderings over three months.

concentrate on basic questions important to cetacean conservation. How many are there? Where do they go seasonally? How do they find food? What constitutes critical whale habitats and how do we protect them?

We are on the verge of a new age in cetology. Space technology can be easier, more accurate, and more cost-effective than many surface-based methods for studying whales. Satellites already give oceanographers an infrared view of sea surface temperatures, and someday may be able to image individual whales at the surface in sufficient detail to determine their species. The attraction whales have for biologically productive areas such as thermal fronts, eddies, and upwellings may result in future Argos-monitored whales significantly supplementing the physical oceanography data from these transitory features.

An Aid to Defining Critical Habitats

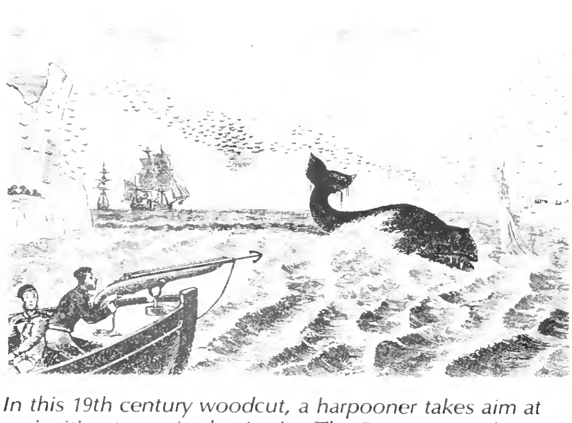
Gray whales were hunted to near-extinction because their critical habitats—migratory paths and breeding/calving grounds—were known. Protection of those habitats has now allowed the species to recover to an estimated 20,000 individuals, near the pre-exploitation number (box, pp. 12–13). In contrast, right whale populations have yet to recover from whaling despite half a century of complete international protection; part of this difference is in the reproductive rate of the two species, and part due to man. Originally found in all the oceans of the world, right whale sightings in some regions are so rare as to be noteworthy, while in other areas there seem to be small signs of recovery. The calving interval for mature female right whales appears to be three to five years, making their population grow much slower than mature gray whales that calve every other year. In the North Atlantic, the right whale population is estimated at less than 350 individuals, and painstaking observations by Scott D. Kraus of the New England Aquarium have revealed that 70 percent of the population is scarred from ship collisions or fishing gear entanglements. Thus, man still plays a significant role in the survival of the North Atlantic right whale even without whaling.

Despite a well-known spring and summer feeding season in the Gulf of Maine, there is only scant evidence of the distribution of the right whale during the rest of the year. Females with calves have been observed off the Southeast U.S. Coast in winter, but the whereabouts of most of the population is a mystery. Not knowing the critical migration, feeding, breeding, and calving habitats of these animals makes it impossible to provide them with adequate protection. Abundance and distribution information is a fundamental step in wildlife management, and becomes critical when a species is depleted. Federal agencies responsible for the development of fishing (National Marine Fisheries Service) and offshore oil and gas (Mineral Management Service) have supported basic cetacean studies during the last 15 years, but there are many important details we still need to learn. It is likely that space technology will provide many of the answers to the most basic and sophisticated questions we are still asking about whales.

While it is presently possible to monitor the locations and activities of hundreds of radio-tagged whales by satellite, the reality is that only a few whales have been successfully instrumented. We are just beginning to see the potential for using satellite-monitored whales to describe their preferred habitats, behaviors, and critical requirements. It remains to be seen, however, whether we will adequately protect important whale habitats once they are identified and ignorance is no longer an excuse. □

Acknowledgments

Parts of the work reported here were done in collaboration with Peter Beamish, Joseph Geraci, Jon Lien, and John Prescott, with support from the Minerals Management Service, NOAA, the New England Aquarium, and the Office of Naval Research.



In this 19th century woodcut, a harpooner takes aim at an inviting target in the Arctic. (The Bettmann Archive)

Even the most skilled whaleboat crews found that the hunt held many dangers. (The Bettmann Archive)

How Brainy Are Cetaceans?

by Margaret Klinowska

Why bother to save the whales? A reason that is often given is that they are very clever animals who deserve better treatment. Many people seem to believe that cetaceans are extremely intelligent, and that they probably spend much of their time in deep and meaningful conversation or contemplation. These beliefs are based mainly on the brains of cetaceans, which are usually described as large and complex. As further "proof," there is the ability of cetaceans to learn complicated tricks, not to mention all the stories of the sailors who have been rescued by them. The truth is somewhat different.

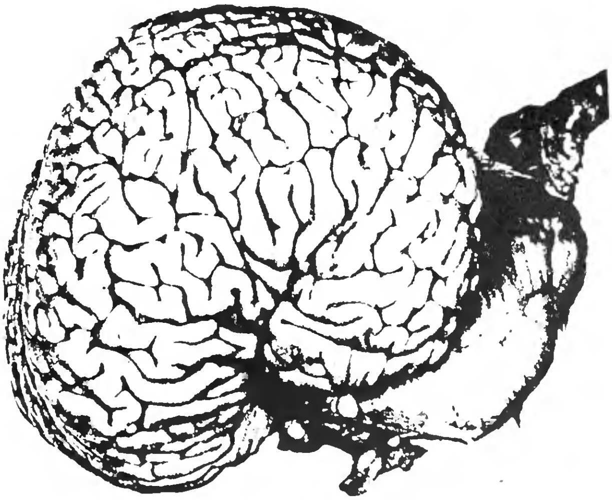
In most species of cetaceans, the brain is neither very large nor especially complex. The blue whale, for example, has a very small brain compared with the rest of its body. The brain of a blue whale may be up to six times larger than that of a human, but as the animal itself is 15 times longer and about 750 times heavier than a human, it is really not very well endowed with brains.

The idea that the size and surface characteristics of brains are related to the intelligence of their owners was popular among neuroanatomists around the turn of the century. It received a severe blow when investigators set to work on the brains of distinguished people who had bequeathed their bodies to science. The brains of these extraordinary people proved to be disappointingly ordinary.

Too Complex to Characterize

The subject remained generally out of fashion until the 1960s when John Lilly, a medical doctor by training, became fascinated by the absolute size of cetacean brains. Lilly was convinced that this must indicate a high degree of intelligence, and his work seems to have led to much of the modern interest in the subject. Lilly also believed that the sounds that dolphins made constituted a true language, but despite years of research neither he, nor anyone else, has substantiated this claim (article, pp. 80–83).

Comparative studies have shown that some cetaceans, for example, toothed whales such as the orca (killer whale) and sperm whale, do have a relative brain size similar to that of humans. But other research demonstrates that brain size isn't necessarily related to intelligence. For example, Giorgio Pilleri and his colleagues at the Brain Anatomy Institute at the University of Bern in Switzerland made an exhaustive study of brain size in relation to behavior among rodents. They


The brain of a bottlenose dolphin is comparable in size to the human brain and displays intricate folding, but the cortex, or "modern" brain, lacks features found in the brains of primates and many other mammals.

concluded that intelligence, whether human or animal, is too complex to characterize with a single numerical index. They also found that cerebral quotients—which express relative brain and body size—provide no conclusive index of intelligence among mammals.

Euan Macphail, of York University in England, looked more widely at the connection between brain and behavior among vertebrates as a whole. He also found that neither the size nor the characteristics of the brain was a satisfactory indicator of intelligence in a species, because there were too many anomalies. One particular example is the spiny anteater, an egg-laying mammal related to the duck-billed platypus. This animal has a neocortex (the so-called "modern" part of the brain, which is very well developed in primates, especially humans) that, compared with its body size, is even larger

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than the human neocortex. Despite this, nobody has yet advanced any claims for the superior intelligence of spiny anteaters.

The newest studies of dolphin brains show that they have not developed the latest stage in the evolution of the brain. Their cortex seems to be lacking some features that are characteristic of primates and many other mammals. It seems that these structures started to evolve among land mammals about 50 million years ago, while the ancestors of modern cetaceans returned to the water a few million years earlier. Even the most advanced cetacean brains seem to be stuck at a stage called the paralimbic-parinsular, which is the most primitive stage in land mammals.

It many respects, then, the cetacean brain is actually quite primitive. It retains all the structures found in primitive mammals, such as hedgehogs and bats. It shows none of the structural differences from area to area typical of advanced brains like those of primates. The regions of the cortex are not separated by so-called associative areas, as they are in most other mammals, but they do seem to be arranged in much the same order as we imagine they were in the ancestor of all mammals.

Wiping Out Useless Memories

A possible clue to account for large brains might be provided by the theory of dreaming that Francis Crick, of the Salk Institute, and Graeme Mitchison, of the Medical Research Council Laboratory of Molecular Biology in Cambridge, England came up with in 1983. Crick and Mitchison said that rapid-eye-movement sleep (REM sleep, or paradoxical sleep, which is associated with dreaming) acts to remove undesirable interactions from networks of cells in the cerebral cortex. They called this process, which is the opposite of learning but different from forgetting, "reverse learning." It clears space in the brain, wiping out useless memories to make way for new ones. Animals that cannot use this system need some other way to avoid overloading their neural networks, for example, by having bigger brains. The spiny anteater and dolphins are so far the only mammals tested that do not have REM sleep. And they have disproportionately large brains. Perhaps they have to have big brains because they cannot dream.

What of the much-vaunted learning ability of cetaceans? Not all species have it, even though the ones that don't perform such tricks have brains as large as the ones that do. And many other animals—for example, sheep dogs, sea lions, and parrots—perform equally impressive feats without being granted a special order of intelligence.

Tales of dolphins helping swimmers and sailors from danger are also often quoted in support of cetacean intelligence. One hears little, perhaps for obvious reasons, from those who were not guided in the correct direction. And there are well-documented cases of apparently unprovoked dolphins attacking swimmers, pushing swimmers out to sea rather than back to land and preventing people from getting back into their craft. This does not prove that dolphins are not intelligent, but it does suggest that they are not always as benign as they are painted. We should be very careful before assigning animals anthropomorphic motives.

David Gaskin made a thorough review of all the evidence for social evolution, communication and intelligence among cetaceans. He concluded that observations of free-living animals at that time did not support the idea that they have a complicated social life. He says there is "little evidence of behavioral complexity beyond that of a herd of cows or deer." He points out that living groups are generally fluid, with a polygynous mating system in which males mate with several females, but play no special social role and have no bond with their offspring. They gather information about their environment, and broadcast it, but there is no "intent," as we would understand the term, behind this broadcasting. They can identify themselves individually, by sounds and body language, which allows members of a group to work together and to recognize the emotional state of other members. Lilly's early claims notwithstanding, studies of cetacean sounds do not even begin to offer evidence that they have anything approaching a language. There is just not enough variety in the sounds.

A Mind in the Water

People have long dreamed of being able to talk to the animals. Even more exciting is the idea of a "mind in the water," which could not only answer back but also provide troubled humans with philosophical guidance garnered from millions of years of peaceful existence. It is little wonder that such dreams have gained a remarkable hold on the popular imagination. I am sure they have also contributed to the remarkable international efforts to preserve the great whales from the threat of uncontrolled commercial whaling. It is ironic that in the meantime people have brought several species of dolphin to the brink of biological extinction by killing them, deliberately and accidentally. Dreams of minds in the water did nothing to help them. Or perhaps we thought they were bright enough to look after themselves. They are not, and nor, it seems, are any of the cetaceans.

In the *Just So Stories*, Rudyard Kipling included an instructive little poem about his

> ". . .six honest serving men" (They taught me all I knew); "Their names are What and Why and When and How and Where and Who."

We know well enough that cetaceans can tell one another what, where, and who. There is not yet any solid evidence that they can communicate about when, how, or why. When it comes to learning and intellect, whales, dolphins and porpoises are, I fear, three serving men short. □

The Marine Mammal Protection Act

A First of Its Kind Anywhere

by Robert J. Hofman

Before the passage of the Marine Mammal Protection Act (MMPA) in 1972, conservation and protection of marine mammals in areas under U.S. jurisdiction were the responsibility of coastal states or international authorities such as the International Whaling Commission (IWC), the North Pacific Fur Seal Commission, and the International Commission on North Atlantic Fisheries. But the conservation efforts of some of these bodies were not very effective. Of particular concern were the IWC's weak regulation of commercial whaling, the large "incidental" take* of porpoises by the U.S. tuna purse-seine fleet in the eastern tropical Pacific, and the clubbing of "baby" harp seals in the North Atlantic. By the late 1960s, many people feared that certain marine mammal species and stocks were in danger of extinction because of human activities.

Passed in response to these rising concerns, the MMPA established a moratorium on taking marine mammals in U.S. waters and importing marine mammals and marine mammal products into the United States. However, there were some exemptions. The moratorium didn't apply to Indians, Aleuts, or Eskimos in coastal Alaska who hunted marine mammals for subsistence, or making and selling handicrafts. Under a permit system, the act also allowed taking and importing marine mammals for scientific research; for education and public display; and, incidentally, in the course of commercial fishing operations, such as the purse-seine tuna fishery.

In 1981, the act was amended so the Secretaries of Commerce and Interior could waive the permit requirements and allow the incidental but not intentional taking—an important distinction—of "small numbers" of nondepleted** marine mammals by U.S. citizens involved in fisheries and such activities as offshore oil and gas exploration and development. A further amendment in 1986 authorized the taking of

There is continuing concern over the loss of dolphins caught in tuna nets. (Courtesy of NOAA Fisheries)

small numbers of depleted species incidental to activities other than fisheries. More recent amendments provide temporary authority to the secretaries to allow the incidental taking of depleted as well as nondepleted marine mammals during commercial fishing operations.

In addition to these exceptions, the MMPA lets the federal government waive the moratorium on taking marine mammals in certain

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*The term "take" is defined in the act as harassing, hunting, capturing, killing, or attempting to harass, hunt, capture, or kill any marine mammal.

**A marine mammal population is considered to be "depleted" if the Secretary of Commerce or Interior, after consultation with the Marine Mammal Commission and its Committee of Scientific Advisors, determines that the species or stock is below its optimum sustainable level, or the species or stock is listed as endangered or threatened under the Endangered Species Act.

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cases and to return management authority to the states. Only Alaska has sought and received a waiver (for walrus). But Alaska Natives challenged the federal government's decision in court (*People of Togiak v. United States*) because they would have lost their exemption from regulation under the MMPA. The court ruled in their favor, effectively preventing the state from regulating native walrus-hunting, and Alaska subsequently returned management to the U.S. Fish and Wildlife Service (FWS).

Dividing the Regulatory Responsibilities

Under the act, the Secretary of Commerce has responsibility for conservation and protection of cetaceans, seals, and sea lions; while the Secretary of the Interior oversees all other marine mammals (walruses, manatees, dugongs, sea otters, and polar bears). The Commerce Secretary has delegated this responsibility to the National Marine Fisheries Service, an arm of the National Oceanic and Atmospheric Administration (NOAA); and the Interior Secretary to the FWS. Each year the Secretaries are required to provide Congress and the public with a report on the status of marine mammals and what actions, if any, have been taken to ensure their well-being.*

The MMPA created two administrative bodies: the Marine Mammal Commission, and its Committee of Scientific Advisors on Marine Mammals. Their function is to advise federal agencies on measures for marine mammal protection. The commission's three members are appointed by the President with the advice and consent of the Senate, while the nine-member Committee of Scientific Advisors is chosen by the commission chairman. Both groups must be knowledgeable about marine ecology and resource management, and not be in a position to profit from the taking of marine mammals.

The reports and recommendations of the two bodies are matters of public record. Federal agencies must respond to commission recommendations within 120 days. If they aren't followed or adopted, the MMPA requires an explanation in writing to the commission.

What the Act Was Designed to Do

In enacting the MMPA, Congress intended to prevent the depletion of marine mammal species and populations as a result of human activities, and to restore those that have been so affected. Thus, the MMPA's primary objective is to maintain the health and stability of the marine ecosystem and, whenever consistent with this primary objective, to obtain and maintain an optimum sustainable population (OSP) of marine mammals. The act, as amended, defines OSP with respect to any population or stock, as "the number of animals that will result in the maximum productivity of the population of the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element."

For the purpose of managing stocks, NOAA Fisheries and the FWS have interpreted this statutory definition as follows:

> "Optimum sustainable population is a population size which falls within a range. . .that is the largest supportable within the ecosystem to the population level that results in maximum net productivity. Maximum net productivity is the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth, less losses due to natural mortality."

This interpretive definition of OSP has been used as the basis for decisions concerning the status of porpoise stocks affected by the yellowfin tuna purse-seine fishery and a number of other issues requiring OSP determinations.

The Latest Amendments

On 22 May 1987, the Department of Commerce issued a general permit authorizing the take of Dall's porpoise, *Phocoenoides dalli*, in the Japanese North Pacific salmon drift-net fishery. In a lawsuit filed in the U.S. District Court of the District of Columbia, the Kokechik Fishermen's Association, representing Alaska subsistence fishermen, and the Center for Environmental Education, representing several environmental organizations, challenged the department's action. They contended that the permit issued to the Federation of Japan Salmon Fisheries Cooperative Associations violated the MMPA because it covered only Dall's porpoise when it was known that other marine mammals also would be taken, albeit in small numbers. The court ruled in favor of the Kokechik Fishermen's Association and the environmental plaintiffs, finding that certain species (e.g., North Pacific fur seals) not covered by the permit would inevitably be caught if the Japanese were allowed to fish. The court determined that taking even a single individual from a depleted population would be to the stock's disadvantage and couldn't be allowed under the MMPA. Based on these findings, the court invalidated the incidental take permit that had been issued to the Japanese group.

Recognizing that the Kokechik decision could have a severe impact on fisheries, representatives of American environmental groups and the U.S. fishing industry, in May,1988, proposed a limited three-year exemption of the incidental-take permit requirements while more reliable data on the types, levels, and implications of marine mammal-fisheries interactions are acquired. Subsequently, Congress passed and, in November, President Reagan signed legislation

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*Copies of all the commission's annual reports can be obtained from the National Technical Information Service. Copies of the 1988 report, and some earlier reports, can be obtained directly from the commission, 1625 Eye Street, NW, Washington, DC 20006.

Incidental Mortality of Porpoises in the Eastern Tropical Pacific Yellowfin Tuna Purse-Seine Fishery

Year	U.S. Vessels	Non-U.S. Vessels*	TOTAL
1971	246,213	15,715	261,928
1972	368,600	55,078	423,678
1973	206,697	58,278	264,973
1974	147,437	27,245	174,682
1975	166,645	27,812	194,457
1976	108,740	19,482	128,222
1977	25,452	25,901	51,353
1978	19,366	11,147	30,513
1979	17,938	6,837	20,454
1980	15,305	29,598	49,551
1981	17,890	17,146	35,036
1982	23,267	5,065	28,332
1983	8,513	(no estimate available)	
1984	17,732	15,018	32,750
1985	19,205	36,032	55,297
1986	20,692	103,905	124,597
1987	13,992	97,941	111,933
TOTAL	1,443,685	552,198	6,148,756

Data from: Lo and Smith (1986); NOAA Fisheries (1987); and Hall and Boyer (1988).
*Derived from subtracting U.S. from total mortality estimate

(Public Law 100-711) amending the MMPA. Among other things, the amendments:

- Suspend the incidental-take permit requirements until 1 October 1993 for U.S. fishermen (except those engaged in the yellowfin tuna purse-seine fishery in the eastern tropical Pacific) and for foreign fishermen holding valid fishing permits issued pursuant to the Fishery Conservation and Management Act (note: the exemption doesn't apply to the Japanese salmon drift-net fishery in the North Pacific);
- Authorize the Secretary of Commerce to permit the accidental, but not intentional, incidental take of depleted marine mammal species and populations (other than southern sea otters) during the exemption period, provided the take isn't contrary to the provisions of the Endangered Species Act—i.e., the take won't jeopardize the continued existence of the affected species or population—and that the industry seeks to reduce the incidental take of marine mammals to insignificant levels; and
- Require the secretary to recommend to Congress by 1 January 1992 standards and procedures that should govern the incidental take of marine mammals during commercial fishing operations after the expiration of the three-year exemption.

The Taking of Porpoises

When the MMPA was first enacted, several hundred thousand porpoises were being killed each year in the eastern tropical Pacific Ocean because of the practice of "setting-on-porpoise" to catch the large yellowfin tuna that frequently associate with porpoise schools.* In addition to permitting incidental takes of porpoises in this fishery, the act set as an immediate goal that the killing and serious injury rates be reduced to insignificant levels approaching zero. Subsequent actions of NOAA Fisheries and the U.S. tuna industry led to substantial reductions in porpoise losses (from 1977 through 1987, the average annual take by the U.S. tuna purse-seine fleet was approximately 17,500 animals). During this same period, however, the U.S. fleet declined from more than 100 to 34 boats, while the foreign fleet increased from fewer than 10 to more than 70 boats. Under the law then, foreign fishermen weren't required to use the U.S. fleet's porpoise-saving measures, and the incidental take of porpoises increased with the size of the foreign fishing fleet.

Aware of both the peril to the porpoise stocks and to the competitive advantage of the U.S. tuna purse-seine fleet, Congress amended the MMPA in 1984 to require that each nation exporting tuna to the United States provide documentary evidence that it had adopted a program comparable to the U.S. porpoise-protection program and that the average rate of incidental take by its fleet was comparable to the U.S. fleet's.

During an MMPA reauthorization hearing held by the U.S. Senate Committee on Commerce, Science and Transportation last April, it was noted that NOAA Fisheries hadn't yet completed regulations implementing the 1984 amendment; that the U.S. tuna purse-seine fleet had declined by more than 60 percent in the last ten years but that the level of incidental porpoise take by the fleet had not gone down proportionately; and that the estimated level of take by foreign fleets had increased dramatically in 1986 and 1987. In light of these developments, Congress enacted additional amendments last year that required the secretary to find the regulatory programs of other nations unacceptable unless:

- They include, no later than the start of the 1990 fishing season, prohibitions against encircling pure (i.e., single species) schools of certain marine mammals, and conducting sundown sets (during which porpoises are harder to see and remove from nets because of poorer visibility), and to implement other

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*For reasons that still aren't entirely clear, porpoises and yellowfin tuna tend to aggregate in the open sea, with the porpoises swimming above and the tuna below them. Scientists speculate that the animals may be cooperating in feeding. The tuna possibly seek out the porpoises to take advantage of their superior food-finding ability, and, in turn, block the food fish from escaping beyond the porpoises' diving range. In any case, fishermen have long used porpoise sightings as a clue to the presence of yellowfin tuna and set their nets directly on the porpoises to catch the valuable fish below. In a porpoise-saving maneuver called "backing down," the boat backs up after the net is pursed—that is, after its bottom is closed. That causes the trailing edge of the net to sink, letting the encircled porpoises swim clear of it (*Oceanus*, Vol. 21, No. 2, pp. 31–37).

porpoise-saving measures applicable to U.S. vessels;

- The average rate of incidental take by vessels of the harvesting nation is no more than two times that of American vessels by the end of the 1989 fishing season and no more than 1¼ times greater by the end of the 1990 fishing season and thereafter;
- The total number of eastern spinner dolphins, *Stenella longirostris*, and coastal spotted dolphins, *S. attenuata*, taken incidentally during the 1989 and subsequent fishing seasons does not exceed 15 percent and two percent, respectively, of the total number of all marine mammals taken incidentally by vessels of the harvesting nation;
- The rate of incidental takes during the 1989 and subsequent fishing seasons is monitored by the Porpoise Mortality Observer Program of the Inter-American Tropical Tuna Commission or an equivalent international program in which the United States participates and is based upon observer coverage equal to that of U.S. vessels during the same period; and
- The harvesting nation complies with all reasonable requests by the secretary for cooperation in carrying out the scientific research program required by the MMPA.

The amendments also require that the government of any intermediary nation that exports yellowfin tuna or tuna products to the United States provide reasonable proof that these products didn't originate from a country without an appropriate porpoise-protection program. In addition, the amendments affect the U.S. tuna purse-seine fleet. They specify that:

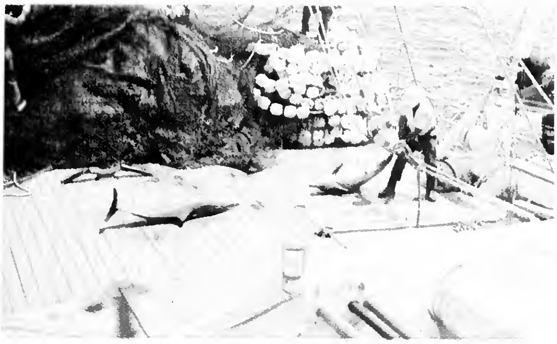
- By 1 January 1989, the Secretary of Commerce issue regulations to ensure that purse-seine sets on marine mammals are completed no later than 30 minutes after sundown;
- By 1 January 1990, the secretary establish performance standards encouraging U.S. fishermen to use the best marine mammal safety techniques and equipment that are economically and technologically practicable;
- The secretary shall prescribe regulations, effective 1 April 1990, prohibiting the use of Class C explosive devices (i.e., large firecrackers) to herd porpoises during fishing operations unless a study shows that the use of the devices doesn't harm or kill porpoises;
- Until at least the 1991 fishing season, each U.S. tuna purse-seiner carry an official observer to conduct research and observe fishing operations during each trip to the eastern tropical Pacific;
- The secretary contract with the National Academy of Sciences to help identify possible alternatives to the practice of setting-on-porpoise to catch tuna and, by 5 December 1989, submit to Congress a plan for developing and implementing any promising techniques; and
- On or before 1 April 1992, the secretary submit to Congress a report describing efforts to reduce the incidental take of porpoise in the yellowfin tuna purse-seine fishery, and propose legislation or other measures to reduce or eliminate it.

Setting a purse-seine net for yellowfin tuna in the eastern tropical Pacific. (Courtesy of NOAA Fisheries)

Restrictions on Importation and Public Display

The act was also amended to allow the secretaries to authorize the importation of depleted marine mammals for medical treatment; to allow capture and relocation, captive maintenance, and other forms of taking that might enhance the survival or recovery of marine mammal species and populations; and to permit importation of marine mammals that were pregnant or nursing at the time of taking or less than eight months old. Previously, the act permitted the taking and importing of depleted species and populations only for scientific research, thus prohibiting many activities that would benefit individual animals or enhance species or population survival. It also prohibited the importation of animals less than eight months old or that were pregnant or nursing when captured, even when such animals as orphaned polar bear cubs faced destruction for lack of maintenance facilities in the countries of origin.

In recent years, hotels, motels, and other institutions not normally associated with public display have requested and received permits to take marine mammals for such purposes. In addition, some organizations have initiated swim-with-dolphin programs. Satisfying these requests requires that more animals be taken from the wild and has raised questions as to what constitutes public display. The 1988 amendments specify that permits for public display may be issued only to an applicant who offers a program for education or conservation purposes that meets the professionally recognized standards of the public display community.



Dolphins that were incidentally trapped during tuna fishing operations. (Courtesy of NOAA Fisheries)

The amendments also respond to the increase in marine mammal research, particularly by students and private citizens with limited scientific training and no affiliation with established academic or research institutions, that isn't subject to peer review. Such activities increase the likelihood that marine mammals will be harassed, injured, or killed in the course of research that produces information of little or no scientific value. Accordingly, the amendments specify that permits for scientific research should only be granted to those applicants who provide persuasive evidence that: (1) their research is likely to contribute to answering a bona fide question of either basic or applied scientific value; (2) the research isn't unnecessarily duplicative; (3) in the case of research that would involve destroying the subjects, it can't reasonably be done using alternative nonlethal techniques; and (4) when the research involves the lethal take of a marine mammal from a depleted species or stock, it will either directly benefit that species or stock, or fulfill a critically important research need.

Placing the Burden of Proof on the User

The Marine Mammal Protection Act of 1972 was the first law anywhere in the world to require that marine mammal management be approached from an ecosystem perspective. It introduced the concept of "optimum sustainable populations" and established the principle that, before taking of marine mammals can be authorized, available biological and ecological information should indicate that the action doesn't have a significant adverse effect on the species or population. It placed the burden of proof on the potential user, rather than on the regulatory agency or the conservation community.

Experience since passage of the act indicates that there have been misconceptions about some provisions, and reasons to modify others. As a result, Congress has amended the act from time to time to make it more workable, while ensuring that appropriate steps are taken to enforce its original objective: to prevent the depletion of marine mammal species and populations because of human activities, and to restore those that have been adversely affected. By and large, in spite of controversies and misunderstandings, especially in its earliest days, the MMPA has worked extremely well.

The latest amendments illustrate the act's evolutionary nature. The success in implementing them, as in implementing the act itself, will depend on a number of factors, including the ability and desire of the regulatory agencies—NOAA Fisheries and the FWS—to carry out the various directives and seek the necessary appropriations; the continuing interest of Congress, the scientific community, affected industries and public-interest groups, as well as the public at large; and the ability of the Marine Mammal Commission to suggest solutions to the complex problems raised by the amendments.

Some key measures to look for in this regard are whether NOAA Fisheries is able to establish by July an effective system of registering and obtaining incidental take and related data from vessels engaged in fisheries that frequently or occasionally catch marine mammals in U.S. waters; whether Mexico and other countries with tuna purse-seine fleets in the eastern tropical Pacific, in the next two years, adopt porpoise-protection programs comparable to the U.S. program and reduce the incidental mortality and serious injury rates to insignificant levels; whether the commission is able to develop by 1 February 1990 ecologically and economically sound guidelines to govern the incidental taking of marine mammals in fisheries other than the yellowfin tuna purse-seine fishery in the eastern tropical Pacific; and whether NOAA Fisheries and the FWS are able to develop broadly acceptable criteria for deciding what public display programs meet professionally recognized standards, and what constitutes bona fide scientific research. □

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Some Basics about the Whales:

Although Herman Melville once described the whale as "that spouting fish with the horizontal tail," we know that whales, dolphins, and porpoises are not fish at all, but rather sleek, warm-blooded, aquatic mammals known collectively as cetaceans (from the Latin and Greek words cetus *and* ketos, *both meaning "whale"). Taxonomically, the order Cetacea consists of three suborders: Archaeoceti, the extinct "ancient whales"; Mysticeti, literally "moustached whales," or baleen whales; and Odontoceti, the "toothed whales." (Marine mammals such as seals, sea lions, manatees, otters, and walruses belong to entirely different orders.)*

Archaeocetes are known only from scattered fossil remains, so interpretations of cetacean origins are very speculative. An elongated body, paddle-like forelimbs, and upward-pointing nostrils show that archaeocetes were well adapted to aquatic life. Although these features are shared by modern whales, there is some debate among paleontologists as to whether archaeocetes gave rise to today's whales, or were an evolutionary dead end.

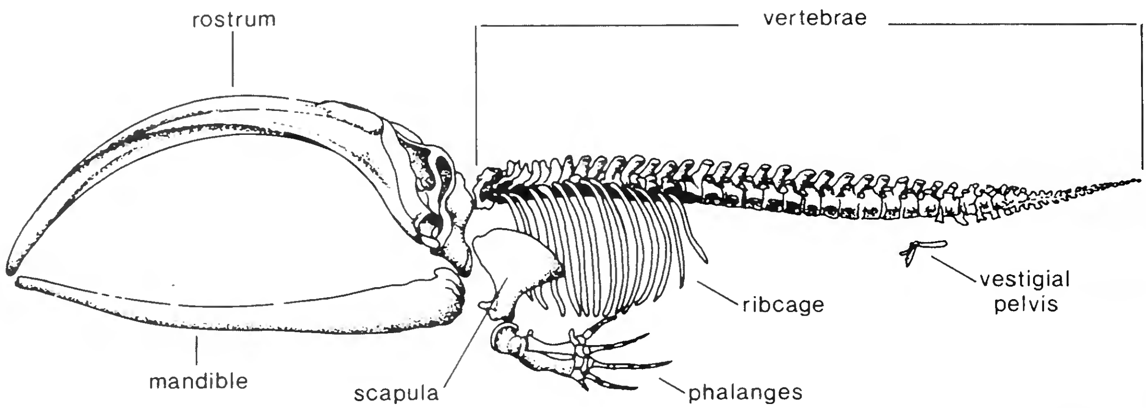
A related controversy is whether baleen and toothed whales had a common ancestor when they abandoned the land for the sea approximately 55 million years ago. An alternative proposal is that they arose from distinct predecessors, converging into similar forms because of their parallel ways of life. Biochemical and genetic studies suggest that cetaceans' closest relatives on land are hoofed mammals, or ungulates, which include deer and elephants.

There are at least 10 species of baleen whales, so named for the brush-like baleen in their mouths. Baleen, or whalebone, is a series of flexible horny plates with frayed insides. It hangs from the roof of the mouth, arranged along both sides like the teeth of a comb. Baleen whales use this coarse filter to strain their food—zooplankton and fish—from the water. Before the invention of resilient plastics and steels in the early 20th century, baleen was in great demand for products such as springs in sofas, buggy whips, and stays in ladies' corsets.

Among the baleen whales are the humpback and gray whales frequently seen by whale watchers; the rare bowhead and right whales; and the largest animal ever to have lived, the blue whale. Baleen whales make many sounds that appear to be used for communication. Their sounds are typically low frequency moans that can travel sometimes for 6 to 12 kilometers. The famous "songs" of male humpback whales contain a variety of repeated sounds and are used as a sexual display during the breeding season.

Scientists list as many as 65 species of toothed cetaceans. Many of the small species, called dolphins and porpoises (box, page 28), have been seen or collected so rarely that this estimate may change as researchers gather more information. This group includes the sperm whale, apotheosized by Melville in Moby-Dick, *and the stars of oceanarium shows, the killer whales and bottlenose dolphins.*

The possession of teeth is a common characteristic of odontocetes, but there are



The bowhead shows typical features of Mysticeti, or baleen whales, one of two suborders of modern cetaceans.

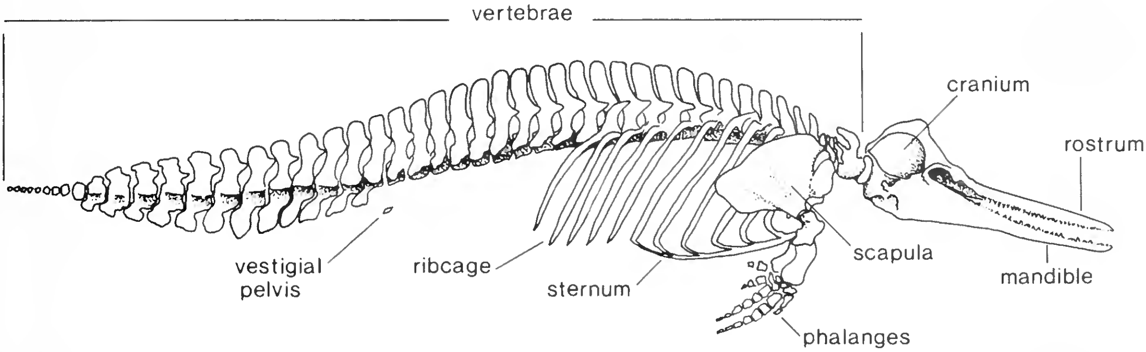
Ancient, Moustached, and Toothed

great variations from species to species. Some dolphins have up to 300 small, sharp teeth. In contrast, the male narwhal has only two teeth, one of which grows long and tusklike, protruding two meters from the front of its head. (The other usually doesn't erupt.) These tusks were sold during the Middle Ages as unicorn horns.

Toothed whales use sound in different ways than baleen whales. Some species find prey by sending out pulses of broadband frequency sound, or clicks, and monitoring the echoes, a process known as echolocation. The whistles of bottlenose dolphins are high pitched, and are used in

through blowholes, usually located high on the head, allowing them to exhale and inhale without interruption of swimming. Offspring are born under water and are helped to the surface for a first gulp of air by the mother and any other nearby whale.

Toothed whales have only one blowhole. Baleen whales have two, side by side. When a whale comes to the surface and "blows," that is expels moist air from its lungs, the shape, size, and direction of the "spout" is often used to identify the type of whale—I can still remember my exhilaration a few years ago at seeing a whale from a ferry



The Indo-Pacific humpbacked dolphin typifies the other modern suborder, Odontoceti, or toothed whales.

some behaviors to identify individuals (article, pp. 80–83).

There are many similarities between baleen and toothed whales. Their torpedo-like shape allows for easy movement through the water. In whales, features that tend to protrude on land mammals have been modified and internalized: teats and genitals are withdrawn into slits, and there are no external ears. Flippers, which are vestiges of forelimbs, are used for slow speed maneuvering and stopping, and can be flattened against the body during rapid movement. In addition, cetaceans are hairless, except for a few bristles on the snouts of certain whales. All cetaceans have a muscular tail that is flattened in a horizontal plane (as opposed to the vertical alignment of most fish tails), and propels the animal by moving up and down.

Even though cetaceans are aquatic, they are air-breathing and so must return periodically to the surface. They breathe

in the Bay of Fundy and identifying it as one of the extremely rare northern right whales by its distinctive V-shaped spout.

Whales, dolphins, and porpoises are found throughout the oceans of the world, both in the open sea and in coastal waters. A few species live exclusively in rivers, and some, such as the Irawaddy dolphin, can go back and forth between fresh water and salt water.

Some large whales, such as the humpback and gray, make long seasonal migrations, generally breeding in the tropics in winter and moving towards the poles to feed in summer. Others seem to roam more irregularly, in response to changing food supplies or temperature. Most small cetaceans, such as pilot whales, do not make long migrations.

The smaller whales are known for their tendency to strand. Individuals or groups of up to several hundred occasionally swim

(continued on next page)

Whale Basics (continued from previous page)

deliberately onto beaches. Some that have not yet gone onto shore have been helped back to the sea by human rescue teams, but grounded animals often swim repeatedly back to shore where they ultimately die from illness, stress, overheating, or pressure on their lungs from their own bulk.

Many theories have been proposed for stranding. Among them: unfamiliarity with the coastline; following prey too close to shore; and escaping from predators. Another theory is that because of the highly social nature of some species, a group may be responding to the distress calls of a stranded individual. Few scientists believe that whales use a magnetic sense to navigate, but those who do contend that local geomagnetic anomalies in certain bays create "magnetic traps" for whales. Another notion is that illness causes their echolocation to misinterpret the depth of the water nearshore. (This explanation was originally claimed for whales that have since been shown not to echolocate.) A recent fanciful proposal is that after 55 million years, whales are reverting to the land habits of ancestors. There has been little or no evidence to support these theories.

William A. Watkins of Woods Hole Oceanographic Institution prefers an explanation for stranding that is related to illness. "Cetaceans are purposeful breathers, needing to think in order to breathe (in contrast with humans, who do so involuntarily). When whales are sick they may not be able to surface properly thus being in danger of drowning. Most live strandings involve sick whales—apparently trying to find a shallow spot to rest on. For many animals, a short rest appears to be enough to get them back to feeling well. Mass strandings nearly always include both healthy and sick individuals, suggesting that the desire of the group to stay together brings well members into water that is too shallow. Then a low tide or stormy seas get them all into trouble."

—Sara L. Ellis
Editorial Assistant, *Oceanus*

What's in a Name?

The terms "whale," "dolphin," and "porpoise" all refer to cetaceans, but what are the origins of these names, and when should we use them? The word "whale" is probably a derivation of the Latin word *squalus*, meaning "sea fish." "Porpoise" comes from the Old English *porpeis*, meaning "swine fish" (from *porcus* for "pig," and *piscis* for "fish"). "Dolphin" has older roots in the Latin and Greek words *delphinis* and *delphis,* which are similar to the Greek, *delphys,* for "womb"; presumably the ancients saw a similarity between the two shapes.

Today we classify cetaceans into two groups: the mysticetes, or baleen whales, and the odontocetes, or toothed whales (box, pp. 26–28). All mysticetes are called whales—from the immense blue whale (up to 30 meters long) to the much smaller pygmy right whale (7 meters). Only the larger species of odontocetes are considered whales, however. These include sperm whales (18 meters), killer whales (10 meters), and white whales or belugas (5 meters).

Smaller odontocetes (1 to 4 meters) are referred to as dolphins or porpoises, depending on the school of thought. Some whale biologists, mainly in the United States, call all these diminutive cetaceans porpoises, which avoids confusing them with the dolphin-fish, or dorado. Other scientists reserve the term porpoise for members of the family Phocoenidae, which includes Dall's porpoise and the harbor porpoise. Animals in this group have blunt noses, which explains the etymological relationship to swine. This contrasts with the jutting beak of most dolphins, as on the famous television star, Flipper, a bottlenose dolphin.

A Hawaiian spinner dolphin. (Photo by Bernd Würsig)

To confuse matters even more, there are a few stubborn marine biologists who call all porpoises and dolphins small whales.

—SLE

To Icelanders, Whaling Is a Godsend

A whale being flensed, from the 13th-century Icelandic code of law, the Jónsbók. (Photo by J. Ólafsdóttir)

by Jóhann Sigurjónsson

Why have whales and whaling attracted so much public attention in recent years? First of all, it can be related to man's failures to take the necessary measures to conserve our environment, that is, to stop overharvesting of natural resources and to avoid the release of harmful wastes into the environment. Here the environment/conservation movement has used the history of overhunting whales as a lesson in the crusade for a cleaner world. If we are not able to stop whaling worldwide, we are told, we are not likely to make any progress in conserving our environment, which is truly threa[illegible] many of our activities. Some organiz[illegible] tell the public that because whales [illegible] intelligent and highly developed [illegible] same right as human beings to [illegible]

Jóhann Sigurjónsson is a senio[illegible] Research Institute, Reykjavik, [illegible] the IWC's Scientific Commi[illegible] of the Icelandic delegation [illegible] and was recently appointed [illegible] to the International Council f[illegible] of the Sea.

harvested. Their aim is therefore the absolute protection of whales rather than conservation and rational utilization of the stocks.

While the author very much sympathizes with the conservation movement in general, the total protection of all whales from human impact, regardless of the status of the stocks, does not seem to be a rational approach toward management of resources in a world of food shortage and poverty. As a citizen of Iceland, a small island in the far north of the North Atlantic, where the 240,000 inhabitants are overwhelmingly dependent on the exploitation of the surrounding seas, I believe the major issue is to secure that no overhunting of any stocks in the area occurs. Any management measure needs therefore to be based on the best scientific knowledge available to safeguard whales as a resource for future generations.

The History of Whaling

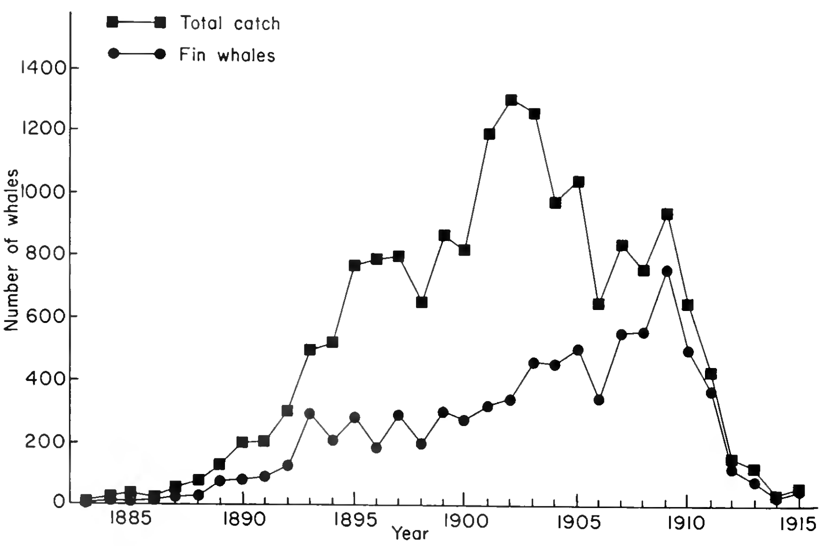
Undeniably, the classic pattern of whale exploitation throughout the world has been that of overhunting, where one stock after another has been depleted. Such development took place as early as in the 16th and 17th centuries, when the black right whales, *Eubalaena glacialis*, and the Greenland right or bowhead whales, *Balaena mysticetus*, were the main targets of the large pelagic fleet operating from Europe in the North Atlantic and Arctic Oceans. In the 18th and 19th centuries the American whalers entered the scene and an intensive hunt of sperm whales, *Physeter catodon*, took place along with other species such as humpback whales, *Megaptera novaeangliae*, taken in smaller numbers.

Although Icelanders were not a part of this early history of whaling in the open seas, the utilization of whales in Iceland as a source of food is well documented in medieval manuscripts dated as early as the 13th century. Whales were harpooned (or speared), driven ashore, or utilized when they were found naturally beached (the Icelandic word *hvalreki*, meaning literally "a stranded whale," has thus acquired its present meaning of "a godsend"), and it often filled a desperate need in a hard year. It was thus not the modest harvest by Icelanders through the centuries that depleted some of the stocks of whales off Iceland in the old days, but rather the large foreign fleets that visited northern waters in search of a quick profit.

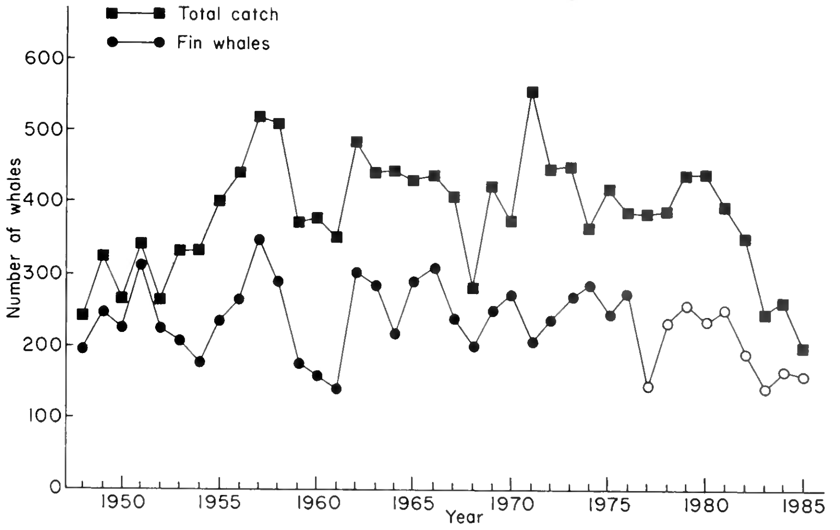
Unfortunately, the lessons of the past went largely unheeded during the so-called era of modern whaling that began some 100 years ago, after the invention of steam ships and the explosive harpoon. Now the numerous and fast-swimming rorquals, blue (*Balaenoptera musculus*), fin (*B. physalus*), sei (*B. borealis*), and humpback whales became the main species of economic interest, as well as the sperm whale. As late as 20 years ago, these whale species were still excessively hunted in some ocean areas, although during the more recent period whaling came under control.

The first successful whaling station in Iceland, set up and owned by Norwegians in 1883 in Alftafjord, West Iceland, heralded the era of modern whaling in Iceland. A second station, also Norwegian-owned, followed in 1889, and from then on foreign stations and vessels multiplied. By 1902, thirty ships were landing some 1,300 whales caught off Iceland with an unknown proportion of whales struck but not retrieved. Before the turn of the century, seven land stations were located in the Western Fjords concentrating on blue, fin, and humpback whales, while sei and sperm whales were taken in smaller numbers.

As the stocks apparently became depleted,



The development of modern whaling in Iceland at the turn of the century before the ban on whaling took effect in 1916. Total number of large (fin, blue, and humpback) whales, and estimated numbers of fin whales landed at whaling stations, 1883–1915.



Large whaling off Iceland by the single land station, located in Hvalfjördur, southwest Iceland, 1948–1985. Total catch, and catch of fin whales. Since 1977 the operation has restricted the fin whale catch to limits set by the IWC (open circles).

most of the stations moved to the East Coast where large whales were still in good numbers. However, after a short period of increased yield, both the total catch of blue whales and catch per vessel rapidly declined, followed by a lesser reduction in fin whales. The decline of the industry is well demonstrated by comparing the bumper year of 1902 with 1914, when only three operating vessels caught a mere 35 whales. Aware of the clear signs of overexploitation, the Icelandic parliament (*Althingi)* proclaimed a ban on all whaling activities to begin at the close of the 1915 season.

This was the first serious measure taken by Icelandic authorities to conserve the whale stocks. Ever since, whaling in Iceland has been subject to strict government control and, since 1949, to the International Whaling Commission (IWC) regulations. No permits were issued for whaling from land stations in Iceland until 1935, when a single station in western Iceland was allowed to operate two or three vessels. This operation ceased during World War II, and the stocks evidently recovered, at least those of fin whales.

After the war those Icelandic authorities had not forgotten the fate of the industry at the turn of the century, and a permit was again issued for only one station, located in Hvalfjördur, in southwest Iceland. The main species caught from this station has always been fin whales (average yearly catch 1948–85: 234 whales), while the catch of sperm (average 82) and sei whales (average 68) was economically far less important. Hunting sperm whales was prohibited in the North Atlantic by the IWC in 1982, following similar protective measures taken in the 1950s for blue and humpback whales, both of which are showing clear signs of recovery.

There is one more aspect to whaling in Iceland, the traditional small-type minke, *B. acutorostrata*, whaling operation by fishermen in coastal waters, mainly in West and North Iceland. From 1914 until the 1950s, annual average catches of minke whales were less than 50. The products were used domestically for human consumption. Then, as the domestic demand increased and new export markets opened, catches gradually increased and became regulated by the IWC in 1977. In recent years the annual catch has been about 200 animals.

Modern Icelandic Management Ideology

For a nation whose exports are largely fish and other marine products—more than 70 percent by listed value—the importance of rational management of these resources is evident. The well known overhunt of whales at the turn of the century and the more recent collapse of commercially valuable fish stocks, such as the capelin, *Mallotus villosus*, and herring, *Clupea harengus*, emphasize the need for the strictest regulatory measures to be imposed on fisheries and ensure the rational utilization of the resources.

In the last few years in Iceland, both scientists and the fisheries management have seriously discussed the so-called multispecies management, whereby measures taken aim at the optimum yield of the harvest in biological, economic, or social terms. Although the development of the multispecies concept is still in its earliest phase, it is being recognized as a future goal in the management. Also of concern is that whales in Icelandic waters probably consume far more food than the total harvest of the fishing fleet in the area. Much of the food is, however, of no direct economic value, although the whales may in general constitute a significant competitor to some of the commercially valuable fish species. More evident are the interactions between the fisheries and the killer whales, *Orcinus orca*, that

aggregate annually on the herring grounds, consuming significant quantities of fish, and often interfering with the fishing operation. Another example is the humpback whale, now alleged to interfere with the important capelin fishery off northern Iceland during winter. Recently, major damages of fishing gear and loss of catches due to humpbacks are being reported as a serious threat to the industry.

It is perhaps easy to understand the categorical view of urban dwellers in the United States or continental Europe, where the environment is under immediate threat by human activities and where many species of animals have disappeared from the local fauna, that no harvesting of whales should be permitted. But such an attitude is hard to understand for the inhabitants of the sparsely populated and harsh northern regions, where pollution on land or in the sea is not at present a direct threat to animal life, where the resources of the sea are practically the only ones available to support life, and where most of the stocks of whales are in healthy condition. The pledge to stop whaling in Iceland for the unforseeable future means, in reality, that one of the few nations that happened to utilize this resource successfully will be punished by those who did not. It would be equivalent to banning the hunting of caribou in the Canadian Arctic because stocks elsewhere had become endangered.

The IWC's Role

After several decades of major whaling operations, including the large-scale expeditions to the Southern Ocean from the beginning of this century, the International Convention for the Regulation of Whaling was signed by 14 countries. The convention took effect in 1948 and was the framework of the newly established IWC. The aim of the convention is to provide a proper conservation and management of the world's whale stocks as a resource, and the orderly development of the whaling industry.

In its early years, the IWC devoted a great deal of effort to biological research and related studies necessary for conservation and management of the whale stocks. Because quantitative stock assessments were lacking, scientists had great difficulties in convincing the whaling industry about the progressive depletion of the stocks. The whale fishery was so competitive, especially in the Antarctic, that it drove the many nations involved in whaling at that time to take as many whales as possible. "Otherwise somebody else would get the share," went the argument.

It was not until the early 1960s that due note was taken of the recommendations made by the scientists, in particular after the independent group of scientists appointed by the commission, The Committee of Three (later Committee of Four), was established to review the status of the stocks. These scientists introduced new methods to assess whale stocks on which proposals of catches and protection of a number of stocks in the following years were based. And after the so-called New Management Procedure (NMP) was adopted in 1975 as a basis for advice made by the Scientific Committee of the IWC, one can say that all endangered stocks became protected by the commission.*

The Moratorium Issue

Although the whale conservation movement had won a victory by the late 1970s, the call for a moratorium on commercial whaling from conservation groups and from several member nations of the IWC hadn't yet gained sufficient support to be adopted. During its meeting in 1972, the IWC's Scientific Committee concluded that "a blanket moratorium would not be justified scientifically since prudent management requires regulation of the stocks individually. It would probably also bring about a reduction in the amount of research whereas there is a prime need for substantial increase in research activity."

In 1972, the IWC had 14 member nations, of which eight, or 57 percent, conducted commercial whaling. By 1982, however, the situation was completely different. The member nations had increased to 39, of which seven, or 23 percent, conducted commercial whaling, and three—the United States, the Soviet Union, and Denmark (Greenland)—caught whales under the so-called aboriginal/subsistence scheme whereby their indigenous northern populations were allowed to continue their traditional hunts. A number of proposals for ending commercial whaling were on the commission's agenda in 1982. One of these was adopted (by a vote of 25 to 7, with 5 abstentions). It called for phasing out commercial whaling over a period of three years and setting zero-catch limits on all stocks of whales for the 1985/86 Antarctic season and the 1986 season elsewhere. Interestingly, the Scientific Committee was still not able to support the moratorium proposal on purely scientific or management grounds, although some members voiced their belief that a halt in whaling might give an opportunity to conduct an in-depth study of the status of the world's whale stocks.

In principle, the decision on zero-catch limits does not rule out the resumption of whaling if scientific evidence shows that stocks are able to support catches. It will, however, be difficult to change this provision, since a three-quarters majority of votes in the commission is required. Nevertheless, the decision provides an important task for the commission to carry out. The commission decided that by no later than 1990, a review of the effects of this decision on

*The NMP divides stocks into clearly defined categories according to their current status, based on the most recent assessment of the Scientific Committee and the principle that all whale stocks should be stabilized at a level of the maximum sustainable yield. Catch limits can be recommended after predetermined procedures, but the system protects all stocks from commercial catches that are below 54 percent of their original level.

the whale stocks, a comprehensive assessment, would be undertaken for subsequent consideration of establishing other catch limits.

Since 1982, the definition, timing and implementation of the comprehensive assessment has been a constant bone of contention. It was not until April 1986 that the Scientific Committee and the commission adopted a specific proposal assuming the comprehensive assessment implied not only an assessment of the effect of the zero-catch limit on the stocks, but more importantly, an in-depth evaluation of the current status of the stocks in the light of present management objectives and procedures. The committee agreed that it would need to:

- review and revise stock assessment methods,
- collect new information to facilitate and improve assessments, and
- examine alternative management regimes.

In 1985, the Scientific Committee had noted that for many important stocks currently protected, no new information had been obtained since exploitation had ceased. In 1986, the committee concluded that if current trends in whale populations were to be studied seriously, IWC member nations should give a high priority to continuing monitoring studies. The committee further assumed that all national research programs would at least continue at their present levels and that new resources would be provided by the commission and member nations in order to accomplish the comprehensive assessment.

When the IWC voted for the temporary ban on whaling in 1982, the Icelandic Government had to decide whether or not to lodge an objection, and thus not be bound by it. The *Althingi*, after long hours of debate, voted 29 to 28 against objecting to the ban. The government announced it would act accordingly. It was a difficult and controversial decision that involved the rights of a coastal state to utilize the living resources of the sea in a rational manner, and to defend the interests of a well established whaling industry that had functioned for 35 years without signs of endangering the stocks. It was also felt unfair that exempted from the ban were the so-called aboriginal hunt, which is not very different from the traditional minke whaling in Iceland (now defined as commercial), and the yearly incidental killing of tens of thousands of dolphins in the tuna fishery, mainly in the Pacific.

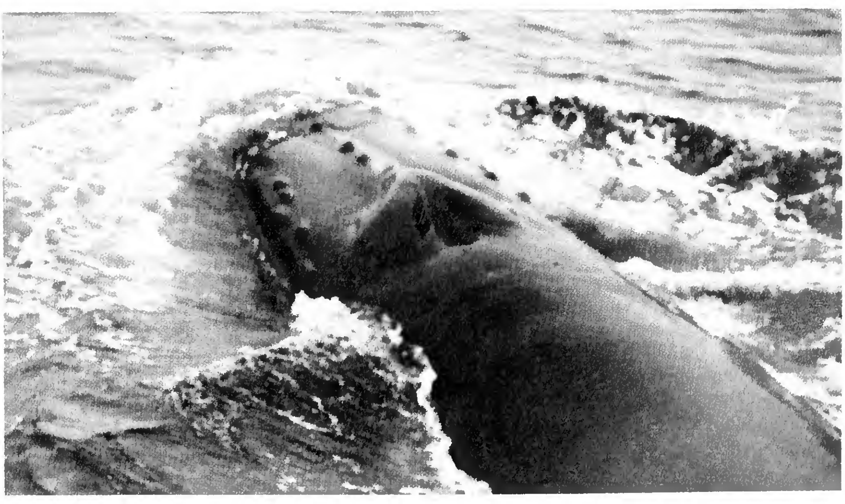
Foreign intervention had also to be considered. Particularly important was the urging by the U.S. authorities that no objection be lodged against the IWC measure, and the overt threat by U.S. conservationists and private companies of their intention to boycott Iceland's frozen seafood products. However, common to all views expressed was that the IWC decision calling for intensified research of the whale stocks was very important. That whales constitute an integral part of the marine ecosystem around Iceland that should be conserved and utilized rationally was never an issue of dispute.

The government's policy on the issue was thus clearly outlined by the *Althingi*: Iceland would abide by the IWC decision on the temporary ban on commercial whaling, and greatly intensify the research on the whale stocks in order to form a policy by 1990, based on the best scientific knowledge.

The Research Program, 1986–1989

The government requested the Marine Research Institute, its main advisory body on marine resource management, to design and implement a four-year research program to take effect in 1986. A review of the results was to be made available to the scientific community and the public in spring 1990.

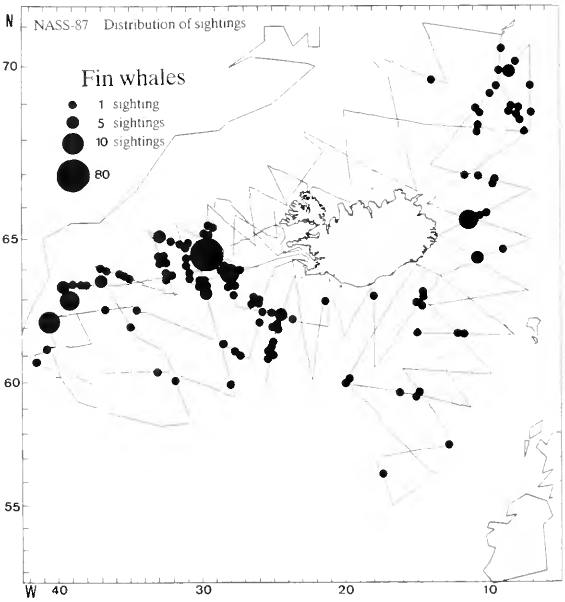
The research program is an ambitious one, and substantial funding has been allocated to it. It comprises more than 30 separate research projects, addressing the different aspects of stock



Humpback whale surfacing. The stock off Iceland was seriously depleted at the turn of the century, but has now recovered after decades of protection. (Photo by J. Sigurjónsson).

assessment, management, and ecology of whales in the waters around Iceland.

The program consists partly of research based on material obtained by direct take and examination of whale carcasses. However, most of the research is based on nonlethal techniques, such as photoidentification, biopsy dart sampling, radio-tagging, and sighting surveys. In conjunction with the research, the Icelandic government issued permits to catch a limited number of fin and sei whales for scientific purposes—80 fin whales in each of the 1986–'88 seasons and 40, 20, and 10 sei whales



Distribution of fin whale sightings during vessel surveys by Iceland, June–July 1987.

successively, in the same years. To maximize the use of the catch, Icelandic authorities have formally offered foreign experts in whale biology access to all scientific material and the research facilities where the whales are examined. Scientists from a number of countries have made use of this unique opportunity to investigate large whales.

The experimental catch has made possible studies of changes in growth rate and maturity, yearly fluctuations in sexual condition and pregnancy rates, and the energetic status of the whales with special respect to reproductive status and the environmental conditions on the whaling grounds. Biochemical studies for stock identification and the development of the so-called DNA-fingerprint method for individual identification of large whales are also under way. Many of these studies would not have been possible during normal whaling operation or without the special arrangements made in connection with the experimental catch.

The ongoing research has made a substantive addition to our knowledge of large whales off Iceland. The studies on energetics have given results essential for ecological modeling of the whale stocks. Of interest are the findings that show a close relationship between the energetic status of the animals and fecundity, which is of importance when monitoring the productivity of the stock. The experimental catch has also revealed important findings regarding between-year fluctuations in ovulation rates in fin whales. It is becoming evident that an application of constant values for fecundity in the present assessment models is a rather unreliable procedure; the yearly changes are simply too big to allow such robust methods to be used. The animals seem to be more sensitive to environmental fluctuations than had been thought.

Earlier findings derived from studies on age-length relationship in the fin whale catch have shown increased growth rate and decline in age at sexual maturity in animals born prior to 1970. The results obtained more recently, partly by the research catch, indicate reversed growth rate and increase in age at maturity. It must therefore be stressed that only by continued monitoring of the biological features of the stocks can one expect to come to conclusions about the validity of the present simplistic population models. For instance, it is crucial for an improved understanding of the possible range of maximum sustainable yield rates (whether one can harvest one to four percent of the stock size each year or even more) to have reliable information on the age at maturity as well as the fecundity rate.

Electrophoretic studies showing the presence of genetically distinct populations of fin and sei whales are also an important element of the research. The results show that only one stock of fin and sei whales enter the area, and an apparent difference in biochemical composition in fin whales off Iceland and Spain has been demonstrated. The first steps toward applying the DNA-fingerprint method on fin and sei whales have been taken. Samples from the catch of large whales were offered for the ongoing IWC contract study on biogenetics. This is in fact the only source of samples for these species. Material from mother-fetus pairs has demonstrated simple Mendelian transmission. Although, as yet, interpretation of the detected differences is far from simple, the material obtained will play a key role in understanding the transmission of patterns of the DNA. A special project to develop species-specific probes for large baleen whales is under way. The potential of such methods is evident, although the actual applicability of the method has perhaps been exaggerated; the DNA-fingerprint method is still at a developing stage as regards large whales. However, when the technique has been refined, it can be a very powerful tool. But of course the limitations will always be the costly sampling part of such research, at least for species that occur in the open waters like fin and sei whales off Iceland, or minke whales in the Antarctic.

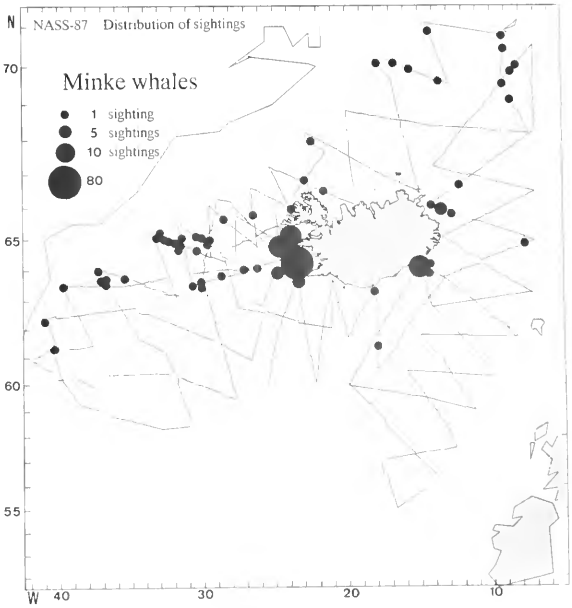
Undoubtedly the results of the sighting surveys off Iceland in 1986 and 1987 are, as yet, the most significant findings of the research program. As a part of international efforts in the northeastern Atlantic in 1987, the North Atlantic Sightings Survey 1987 (NASS-87), Iceland allocated three ocean-going vessels for five weeks each and one aircraft. Eight vessels and two aircraft scouted the vast ocean area from West Greenland to the Norwegian coast, and from Spitzbergen and the Barents Sea to the Spanish coast. The cruises were designed with special emphasis on these two species. Based on the surveys, it is estimated that the size of the East Greenland/Iceland stock of fin whales is 6,000 to 7,000 animals, while minke whales in the survey area (East Greenland/Iceland/Jan Mayen regarded as a separate stock) were estimated about 20,000. Both these stocks appear therefore to be in a healthy state, despite decades of harvesting.

All other whale species were recorded during the survey, including the once very rare humpback whale, now estimated at somewhat less than 2,000 animals in the survey area covered by the Icelandic vessels. NASS-87, perhaps the largest multinational simultaneous whale sightings survey ever conducted, demonstrates how much can be accomplished by organized cooperation between nations. A second international survey is planned for 1989 (NASS-89), to which even more resources will be allocated, possibly with an extension of the survey area to the northwestern Atlantic.

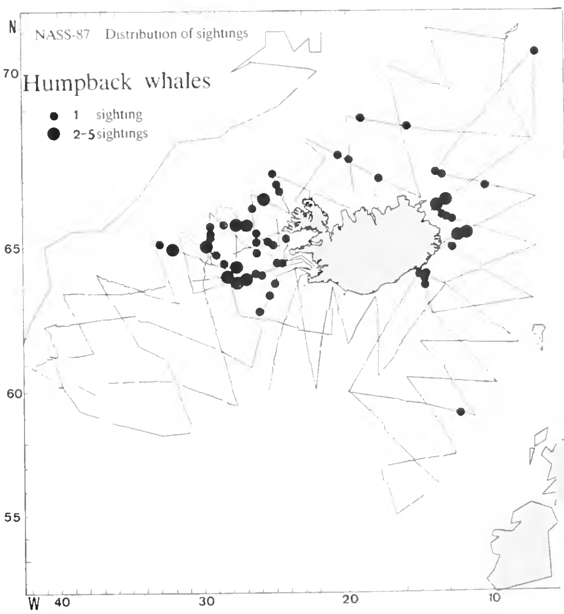
The research activities by Iceland have been subject to criticism by some IWC members as well as by some nongovernmental environmental groups. Some organizations have even used the very limited scientific catch as a reason to conduct boycott actions against Icelandic fish and other exports. It is being alleged that the issuance of scientific permits is a circumvention of the temporary ban on commercial whaling, and that it is not at all necessary to catch whales for research purposes.

The boycott actions and insulting attacks singled out against one nation are of course a very serious matter in itself. When such actions are repeated often enough, the public may have difficulties in evaluating what is right and what is wrong. Such actions remind one of the dangerous fanaticism practiced in the past, but which has not been judged sympathetically by history. It is frightening that a catch of a relatively small number of whales, which are by no means in a threatened status can create such a vulgar undertaking. It has been suggested that the anti-Iceland campaign is simply a ploy for raising funds by some conservation groups to help secure their existence and fight other issues, such as the dumping of chemical and nuclear wastes, for which financial support from the public is harder to obtain than for saving the whales, the beautiful creatures of the oceans.

The issuing of scientific permits by IWC member governments is in full compliance with the convention and its regulations. It is highly inappropriate for critics to take only parts of the Icelandic research program and evaluate them in isolation. The whole project needs to be looked at as a package aimed at answering relevant questions regarding stock management in the area. Although major parts of the program are based on nonlethal methods, direct sampling from a fishery often leads to answers to urgent



Distribution of minke whale sightings during vessel surveys by Iceland, June–July 1987.



Distribution of humpback whale sightings during vessel surveys by Iceland June-July 1987.

A small-type minke whaler from the small village Litli-Árskógssandur, North Iceland. Due to IWC's ban on commercial whaling, no minke whales have been caught in Icelandic waters since 1985. Has the old small-type whaling tradition in Iceland been brought to an end? (Photo by J. Sigurjónsson)

questions more quickly and at less cost. Indeed, the program has already given valuable information on the status of the stocks around Iceland, which will improve the basis for future management.

To state that since the whales are processed and sold after they have been sampled is just a continuation of the past commercial operation, is untrue. In the IWC convention it is very clearly stated that all whales landed under special permits are to be fully utilized. Consequently, the products must be processed and sold. But also important here is that when issuing the permits, the government imposed very drastic measures on the industry to ensure that all profits made by the catch process would support further research. Direct funding—excluding costs of running laboratories, whaling vessels and the processing factory—by Iceland to the project, mainly financed from the specially established research fund, is now on the order of $1.5 million, a substantial contribution from a small community. It should also be borne in mind that by the implementation of its wide ranging program, Iceland is one of a very few IWC member nations that have made serious attempts to fulfill the commission's commitment to conduct in-depth research into the stocks before the year 1990.

With far better knowledge on the status of many whale stocks than just several years ago, the whale conservation movement needs now to decide whether all stocks of whales should be totally protected. For the IWC, the year 1990 will be a turning point. The commission will have to form a policy on future whale conservation and management. If the commission is willing to accept its original role as clearly spelled out in its convention, it has to move from an organization of whale protection to a serious organization of conservation and rational utilization of whales as a resource available to mankind.

In the present situation, when many of the world's whale stocks are evidently at an exploitable level, some numbering hundreds of thousands of animals, countries dependent on marine resources will not go along with a total protection of all whale stocks. If there is no change of attitude, a new international management body will eventually be formed, replacing the IWC. This would be an unfortunate fate for an international organization that has great potential, the best expertise in the field, and that some 15 years ago started taking itself seriously after years of failures. The only hope for the IWC is a greater tolerance by its members toward the traditions, culture, and ethics of the communities involved in the exploitation of whales. Why shouldn't this be possible for nations, that besides harvesting the sea, are managing the hunt of their own land mammals, such as the deer and kangaroo? □

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New ways of looking at marine mammals

Photo by J. Michael Williamson, Mingan Island Cetacean Study.

Getting to Know You

by Steven K. Katona

Until about 20 years ago, the predominant method of whale study was to accompany the commercial whaling fleets, dodge the steam saw and flensing knives, and take samples during the few minutes available while the whale was torn apart. Just as the animals were considered bulk commodities, represented in the old logbooks of Yankee whalers and the statistics of the International Whaling Commission by their length and amounts of oil or meat they provided, so biologists gained information from weights and measures of the organs of dead whales.

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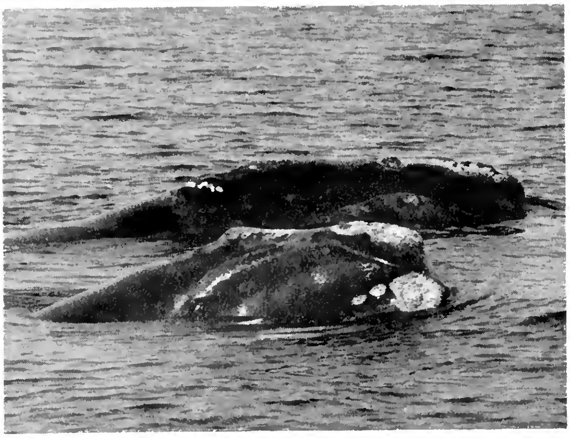


These two right whales, photographed in the Bay of Fundy in 1981, show how distinctive the callosity patterns are in this species. (Photo by Scott D. Kraus)

Important statistics such as reproductive rate were estimated by counting fetuses in female carcasses, or by counting ovarian scars which gives an apparent rate of ovulation. Gunners' bias for killing large animals, concealment of undersized animals by overestimation of length, difficulty in estimating age and in interpreting the ovarian scars, and other factors all contributed to uncertainties in the conclusions. Information on normal behavior was difficult to obtain, since the animals were frequently under pursuit.

Today, whale biologists are focusing their attention, and cameras, on living whales. Instead of dealing with uncertain averages computed from possibly ambiguous tissues without clear ages, new photographic methods are permitting us to make more meaningful, and satisfying, statements about particular whales—that they were born in a certain year, did certain things, and are continuing to do them. We need no longer kill whales to study them.

Revolutionary change in the practice of whale biology began about 1970, when researchers started identifying individual whales photographically, using distinctive natural markings or scar patterns, and searching to resight the same individuals at different times and places while disturbing them as little as possible.

The resulting collections of photographs serve almost like albums of family snapshots. One can see which individuals are male and female; unravel the structure of nuclear and extended families or other social groupings; and by paying attention to the backgrounds of the pictures, learn something of the geographic movements of the individuals involved. If photographs are dated and the photographic record is sufficiently extensive, additional information can be gained, such as growth rate, age at sexual maturity or first reproduction, rate of reproduction, potential longevity, and mortality rate (estimated by the absence of certain individuals from the pictures).

This method of photographically tracking animals is known as photoidentification, or photo-ID, study. And since the date and location of all photographs is recorded in photo-ID studies, all milestones of an animal's life can be revealed by a sufficiently long-term study. Such a record of individual development is called a life history; it summarizes the way an animal has responded to life's challenges.

The kinds of information available from photo-ID studies have a fundamental reality that data from the whaling industry could not provide. Observation of a female whale over many years reveals with certainty her age at first reproduction, number of calves, success of reproduction, and eventual age of reproductive decline.

Efficient use of the photo-ID method requires subject animals to be large, strikingly patterned or scarred, easy to observe, and not too numerous. Furthermore, the markings must be stable enough to permit reidentification throughout the life cycle.

Fin whales usually require several photos before a positive identification can be made. But this one, named "Squid," is easily distinguished by a foot-wide scar on its left side—probably caused by a boat. (Photo by B. Agler)

The first wildlife scientist to use natural markings for studies of individuals, Frank Fraser Darling, worked on gray seals in the British Isles in the late 1930s, but other aquatic scientists did not take advantage of the technique until recently. Detailed, long-term natural-marking studies were first done in the 1950s by terrestrial biologists on large African mammals. Rhinoceroses, giraffes, and zebras were among the first animals studied, partly because they possess most of the characteristics necessary for effective application of the method. During the following decade, elephants, lions, hyenas, and wolves revealed their life secrets to scientists using this method. In the late 1960s and subsequently, the method was applied to our primate relatives, chimpanzees and gorillas, and others.

Perhaps aquatic scientists were slow to catch on because many of the species they study are too wide-ranging, numerous, or uniform in appearance. However, Yankee whalers often recounted the wanderings and activities of unusually marked individuals, such as the albinistic sperm whale, *Physeter catodon*, "Mocha Dick," the model for Melville's *Moby-Dick*. Later cetologists also commented on geographical variations in whale pigmentation, or the pattern of body scars in some species, but did not forsee the utility that these markings would come to have.

A Growing Gallery

Not until Roger Payne began his still-continuing studies on southern right whales, *Eubalaena australis*, in 1971, were differences between individuals used systematically to develop life histories. About the same time, Michael A. Bigg began working on killer whales, *Orcinus orca*, in the Pacific Northwest. Several years later, James D. Darling and David H. Hatler used distinctive patterns resulting from piebald white marks, barnacle incrustations, and scars to confirm the return of several gray whales, *Eschrichtius robustus*, to coastal waters near Vancouver Island, British Columbia, for five years.

Since that time, individual identification has shown that 37 different gray whales returned to feed near Vancouver Island in more than one year. The same technique has demonstrated that most of the grays that breed in San Ignatio Lagoon, in Baja California, stay there for only short periods, and has also verified the rapid movement of two single whales to San Ignatio Lagoon from another breeding lagoon—Scammon's. These observations begin to support the idea that the entire gray whale population, now thought to number 20,000, is one genetic unit.

Starting in 1976, and inspired by those successes, Scott D. Kraus and I collaborated with Payne, Jane Frick, Oliver G. Brazier, Judith S. Perkins, and Hal Whitehead, by pooling our photographs of flukes of humpback whales, *Megaptera novaeangliae*, to see whether the black and white patterns on their ventral sides might be useful as individual markers. We were

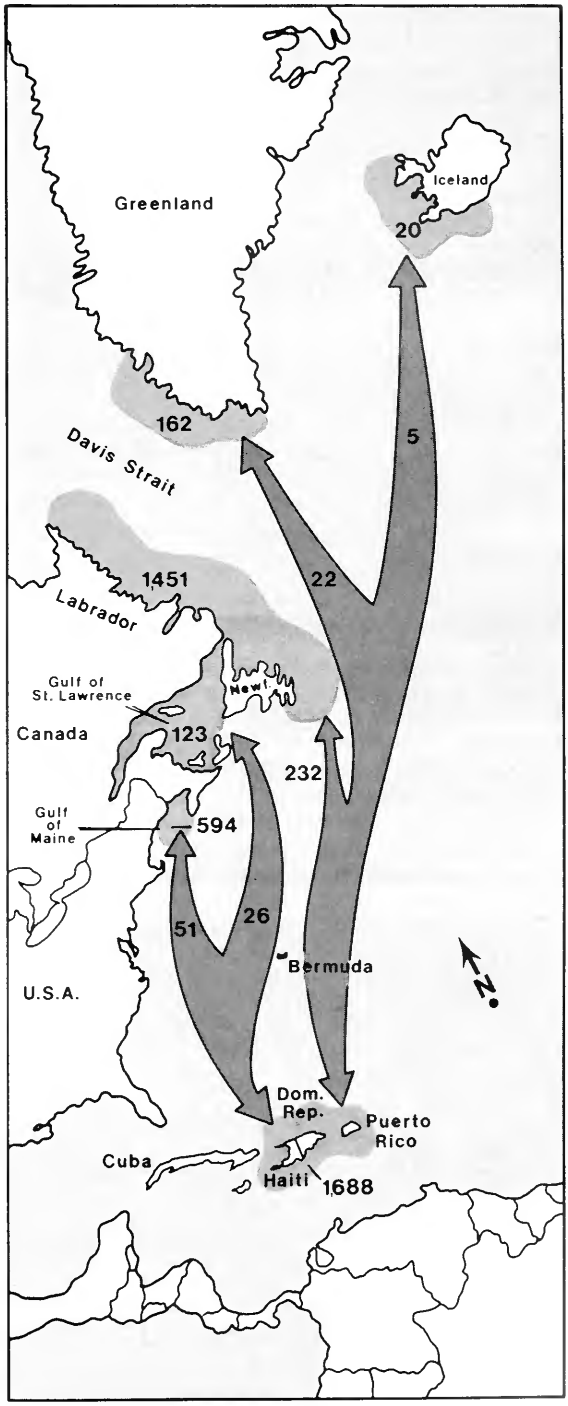
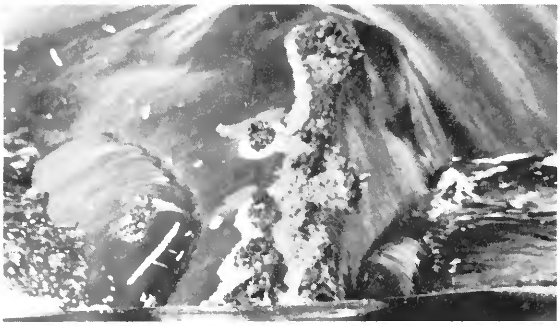
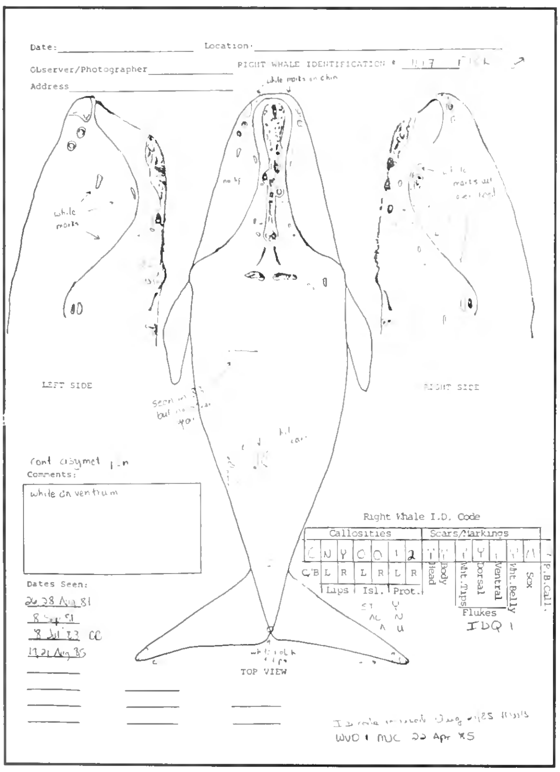


Photo-ID studies show the existence of five distinct humpback feeding aggregations in the western North Atlantic. Although all these whales breed and calve during the winter in a small area of the Caribbean, from summer to summer there is little exchange among feeding groups. Numbers in medium gray indicate humpbacks photographed in the respective northern feeding areas or Caribbean breeding area. Numbers in dark gray indicate individuals identified both in the Caribbean and in the specified northern feeding area.



Portraits of a whale: the flukes; and above left, rostrum; and above right, genital slit of right whale 1147, "Dick." Below, a composite identification chart for northern right whales. The one shown here incorporates information from photo-ID study of Dick. (Photos and chart courtesy of the author)



fortunate that whale No. 0054, photographed by Brazier near Bermuda on 15 April 1976, was among 12 humpback whales we photographed at Mt. Desert Rock, Maine, during late July of that year. With that extra impetus, we contacted everyone in the Atlantic region who might have photographs of humpback flukes, and Kraus produced the first humpback whale catalogue as his final project for graduation from College of the Atlantic (COA). The *North Atlantic Humpback Whale Catalogue*, curated by Judith A. Beard and myself, currently includes nearly 4,000 individual whales, with photographs contributed by more than 200 scientists and research teams. Similar catalogues now exist for humpbacks in the North Pacific (about 2,000 individuals), Australia (about 450), and the Palmer Peninsula in Antarctica (27). Additional local collections have recently begun in several places in South America. These collections have already shown where individuals migrate for feeding and breeding, how often females calve, and how individuals vary in certain behaviors such as feeding.

During the last half dozen years, individual recognition studies have been extended to other species. Following Payne's lead, long-term photo-ID studies of southern right whales are carried out in South Africa by Peter B. Best, and in western Australia by John L. Bannister. The North Atlantic right whale, *Eubalaena glacialis*, the most

Table 1. Identified blue whales—number of years sighted, Gulf of St. Lawrence, 1973–1988.

Number of Years Sighted	Number of Whales Identified	Percent of Population
12	1	.5
11	1	.5
10	0	0.0
9	4	1.9
8	4	1.9
7	2	1.0
6	2	1.0
6	11	5.3
5	12	5.8
4	10	4.8
3	10	4.8
2	17	8.2
1	135	65.2
Totals	**207**	**100.0**

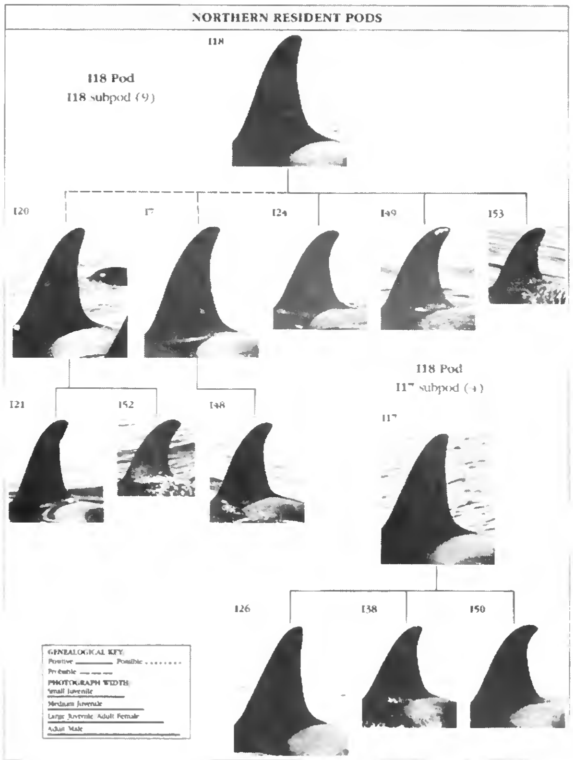
endangered baleen whale in the world, is studied by research workers from the New England Aquarium (NEA), University of Rhode Island, the Center for Coastal Studies in Provincetown, Massachusetts, and the Woods Hole Oceanographic Institution. Kraus, now a research associate at NEA, curates the catalogue of photographs from all groups, which now includes approximately 200 of the estimated 300 to 400 individuals remaining in the Atlantic. As is the case for southern right whales, individuals are distinguished by differences in the size, shape, number, and location of rough, wartlike patches on the head that are called "callosities." The biological function, if any, of callosities is not known; but males, who tend to have more and larger callosities, may use them aggressively against other males while maneuvering to get close to receptive females. Their utility to scientists is unquestionable, however, and information gained from photographs of these strange tissues may be the key to saving the leviathans from extinction.

Richard Sears and colleagues at the Mingan Islands Cetacean Study developed photo-ID techniques for blue whales, *Balaenoptera musculus*, the largest animal ever to have inhabited our planet (Tables 1 and 2), and catalogues now exist for the Gulf of St. Lawrence and also the Gulf of California/California coast region. Fin whales, *B. physalus*, the second largest species ever to have lived, and one of the least understood large whales, are the subject of long-term studies by research groups from Newfoundland to Long Island, New York, as well as European teams. With collaboration fostered by the North Atlantic Marine Mammal Association, researchers have formed the *North Atlantic Finback Catalogue*, curated by Beverly A. Agler and Kim Robertson at COA. Photo-ID has also been used to study sei whales, *B. borealis*, in the Gulf of Maine by Mason T. Weinrich of the Cetacean Research Unit, Gloucester, Massachusetts; Bryde's whales, *B. edeni*, in the Gulf of California by Bernie R. Tershey, Dawn Breese, and Craig S. Strong, at the Moss Landing (California) Marine Laboratories; and minke whales, *B. acutorostrata*, in Puget Sound by Eleanor M. Dorsey.

The results show that the technique is applicable, in appropriate research situations,

Table 2. Identified blue whales – number of years sighted, Sea of Cortez, 1982–1988.

Number of Years Sighted	Number of Whales Identified	Percent of Population
7	1	1.0
6	1	1.0
5	0	0.0
4	6	6.2
3	4	4.1
2	4	4.1
1	81	83.5
Totals	97	100.0



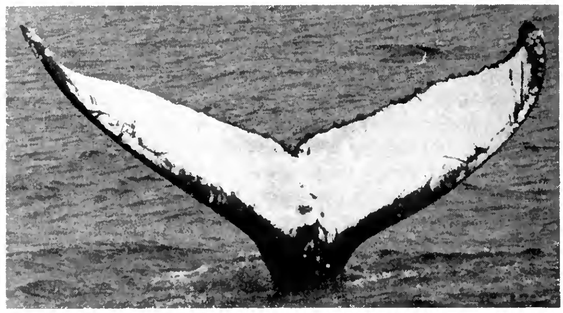
A maternal genealogy of one of the killer whale pods residing along the northeast coast of Vancouver Island, obtained by a variety of photo-ID techniques. (From Killer Whales, *by Michael A. Bigg, Graeme M. Ellis, John K. B. Ford, and Kenneth C. Balcomb)*

Capture-Recapture

The capture-recapture population estimation method was originally developed for studying birds and small mammals. In the simplest version, a number of animals, X, is live-trapped, marked in some way, and then released. A second batch of animals, Y, is trapped at a later date, counted, and the number of marked animals in this second batch, X−n, is noted. The total population, P, can then be estimated by the formula:

$$P = \frac{(X)(Y)}{(X-n)}.$$

Nature has provided marine mammalogists with many species that are naturally premarked. If sufficiently good photographs can be obtained of distinctive scars or patterns on appropriate portions of the body, populations can be estimated by counting the number of appropriate photographs in the two samples and the number of individuals common to both samples, then applying a formula similar to the one above.



The flukes of North Atlantic humpback whale number 0004, known as "Trunk." Left, as photographed in 1976 (Photo by the author). Right, near Brier Island in 1985. (Photo by Carl Haycock, Brier Island Ocean Study)

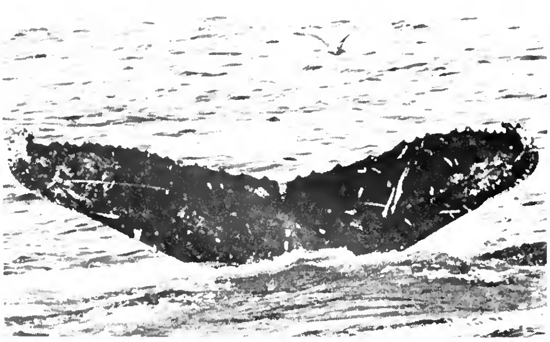
even in species with only subtle individual differences. In nearly all these studies, the whales show somewhat predictable patterns of movement and seasonal migrations, rather like the ungulates of today, with which they share ancestry. There are also indications that some individuals return annually to relatively specific locations for feeding. The most intriguing case so far are Dorsey's minke whales. Most individuals were seen year after year in very localized home ranges, but there are not yet any clues about underlying behavioral mechanisms.

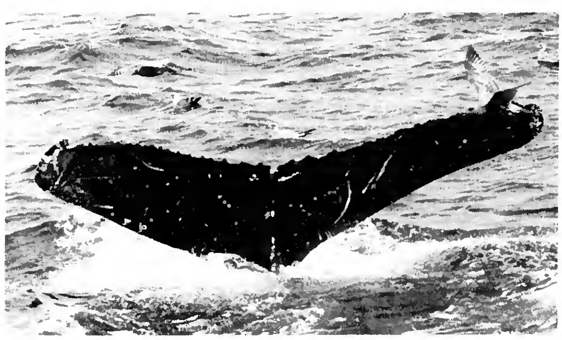
Strategies for Portraiture

Of course, the actual methodology used in these studies isn't quite so simple as photographing family and friends. Marine mammals don't smile and say "krill." Different body parts are individually distinctive in different species. A rocking boat or occasional facefuls of cold salt spray may provide additional challenges. Furthermore, populations are much larger than human families, and the animals spend most or all of the year far out at sea. Fortunately, like human families gathering for the holidays, many individuals tend to return annually to the same places for feeding or breeding, and since these congregations usually take place in nearshore waters, the chances for photographing them again are very good there.

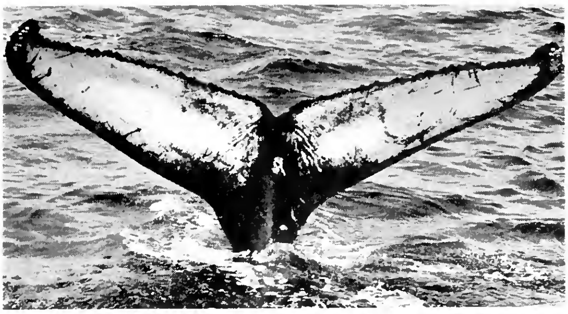
In practice, these investigations mean photographing large numbers of animals, followed by painstaking comparisons of new photographs with those already in the catalogue. Although this somewhat random approach is a circuitous and labor-intensive way to study any particular individual, knowledge slowly accumulates about the life histories of many different animals, ultimately allowing a summary of the mean values and ranges for rates of growth, maturation, reproduction, and mortality. Furthermore, random sampling yields an extra benefit that family photo albums cannot provide, namely the opportunity to estimate the size of the population at large. These calculations are done using a technique called capture-recapture (see box).

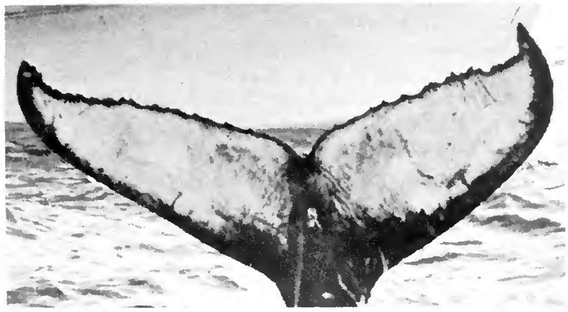
Large-scale photo-ID studies of the smaller toothed cetaceans are limited by their body size, large populations, and other factors; but local populations of Risso's dolphins (*Grampus griseus*), bottlenose dolphins (*Tursiops truncatus*), pilot whales (*Globicephala melas*), and several other species have been studied in this way. The method was also successful for Hal Whitehead of Dalhousie University in his study of sperm whales in the Indian Ocean and around the Galápagos Islands (*Oceanus*, Vol. 30, No. 2, pp. 49–53). Similar studies are being carried out on Atlantic sperm whales by Tom Arnbom of the University of Stockholm. Ocean-wide populations





The flukes of North Atlantic humpback whale number 0178 known as "Comet." Left, on Stellwagen Bank in 1980 (Photo by Charles Mayo, Jr.). Right, on Stellwagen Bank in 1982. (Photo by Mason Weinrich)



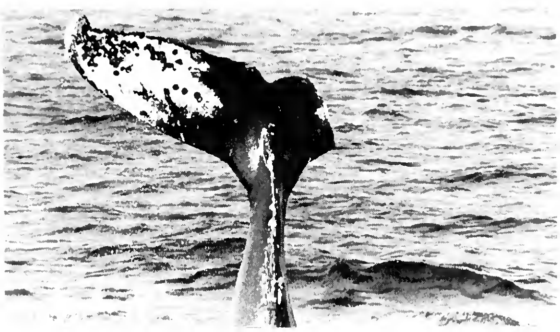


The flukes of North Atlantic humpback whale number 0341, known as "Sirius." Left, in the Gulf of Maine in 1984. Right, in the Gulf of Maine in 1983. (Photos by Peter T. Stevick)

of sperm whales are very large, probably on the order of hundreds of thousands, but females and young form long-lasting groups of about 25 that remain in warm waters, and are amenable to photo-ID studies. Males feed in colder, high-latitude waters, but can be photographed when they visit warm waters for mating. Photo-ID studies may overturn our previous model of sperm whale sexual behavior, because they show large males moving between groups of females every few hours, rather than defending a "harem" for a long time, as was previously thought.

In fact, it is a toothed whale, the killer whale, for which photo-ID studies have provided the most complete record available for any marine mammal. Bigg, Graeme M. Ellis, John K. B. Ford, and Kenneth C. Balcomb have assembled a 20-year record documenting the entire population of killer whales found in the waters of Puget Sound and Vancouver Island, about 325 animals. The study is facilitated by the fact that killer whale families, stable matrilineal groups called pods, stay within relatively discrete home ranges. Every change in pod composition is known, providing a record of births, apparent deaths, and social groupings. Bigg's data suggest that males may live for at least 50 years and females for up to 100 years. Both males and females mature at about 15 years. By age 50 or so, after producing an average of four to six calves, most females stop reproducing, and the rest of their long lifetime could possibly be devoted to helping their offspring and relatives. Female calves stay with the pod for life, but males may move to other pods. Sound recordings of different pods reveal differences in their calls, which may help pod members to identify each other at distance. Killer whales from different regions show differences in saddle-patch form and pigmentation, and dorsal fin shape, indicating they may be genetically distinct.

It is increasingly difficult and time-consuming to curate growing photographic collections, but there is optimism that advances in optical information processing will help photo researchers. A system developed by Beard and Sally A. Mizroch of the National Marine Mammal Laboratory in Seattle, is already helping humpback whale researchers in the Pacific and Atlantic. Fluke patterns are manually scored for color and scars present in each of 14 standard sectors. Codes are entered into a database linked to images of the flukes stored on video disk. The computer finds flukes that most closely resemble each other and displays them serially on the video monitor. Fifty years after Darling's first work with them, gray seals are again in focus. They are the object of another computer-assisted identification system, developed by Lex Hiby of



The flukes of North Atlantic humpback whale number 0153, known as "Silver." Silver's right fluke was severed by a ship's propeller, yet she survived to produce a calf in 1981. Left, on Stellwagen Bank in 1979 (Photo by Charles Mayo, Jr., Center for Coastal Studies). Right, in the Gulf of Maine in 1985. (Courtesy of Center for Coastal Studies)

the Sea Mammal Research Unit, Cambridge, England. That system digitizes photographs of pelage patterns on heads of gray seals, incorporating scaling and three-dimensional rotation for proper alignment of images, then automatically calculates similarity indices between different images as an aid to detecting resightings. Perhaps computers will never become as sophisticated as the human brain in processing visual images, but rapid advances in hardware and software for information storage, optical scanning, and computing make it likely that computer-assisted photoanalysis will make our work more efficient and less tiresome.

Despite their present successes and even greater potential, individual identification studies cannot solve every problem in whale biology. Photoanalysis of huge schools of oceanic dolphins would be an overwhelming task. Broad-ranging photo-ID studies in the enormous area of the Southern Ocean, or in remote arctic waters, would also face formidable problems in logistics, methodology, and cost. Nevertheless, as we come to know more about the animals' habits, the ways in which their populations are structured, and the places they are most likely to aggregate, this technique may have even wider applications than we can now appreciate.

Identification Doesn't Mean Salvation

The future of marine mammal studies looks very bright. In just two decades, photo-ID study grew from a revolutionary technique to a standard method. But incorporation of even newer methods is adding further excitement. Bioassays of known right whales and humpback whales at sea, and bottlenose dolphins along the Florida coast, are already yielding DNA samples that reveal sex, probable parentage, and degrees of substock relationships. These data will facilitate interpreting social behavior, population substructure, migration, and zoogeographical relationships. Another important tool is satellite telemetry (article, pp. 14–18): it is already revealing the actual migration paths of individuals, their swimming speed, respiration rate, depth of dives, and other physiological parameters. Satellite tracking will be necessary to learn about the migrations of species that apparently do not aggregate for breeding, such as blue, fin, and sei whales—and the bowhead (article, pp. 54–62) which inhabits remote, inhospitable waters.

The future of marine mammals themselves, in my opinion, is not so bright. As our own species comes to dominate more of the Earth and its waters, whales, dolphins, and other marine mammals will suffer increasingly. Collisions with ships and entanglement in fishing gear may already be compromising the recovery of Atlantic right whales, and ships are getting larger and faster every year. More than 100,000 dolphins die each year in the eastern tropical Pacific tuna fishery, including thousands killed by U.S. fishermen. Countless thousands of marine mammals, diving birds, and turtles die in gill nets, casualties of an indiscriminate fishing method. Our primitive and irresponsible methods of sewage and waste disposal are killing harbors and bays and polluting continental shelf waters that are home to the baleen whales and many smaller species. Contamination by agricultural and industrial chemicals and wastes is already killing belugas in the Gulf of St. Lawrence.

Other species are surely affected as well. Seal and sea lion pups die from entanglement when fishing nets discarded or lost at sea drift onto their breeding rookeries. Individuals of at least seven species of cetaceans have been killed by ingestion of plastic objects, as have many marine birds and turtles. Noise from ships, mineral and petroleum exploration activities, and other sources is probably affecting the acoustic activities of whales and dolphins. Amidst all these stresses, the food supply for marine mammals is probably shrinking as human fishermen do all they can to supply our burgeoning population and our farm animals with foods from the sea.

If our species doesn't stop population growth, and doesn't stop using the ocean as a dump, I'm fairly certain that most of the marine mammals will be gone in several centuries. Future generations should never forgive us if that comes to pass, because we have adequate warning of the consequences of our actions. □

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A View from the Other Side

Why the Japanese Are So Stubborn About Whaling

by Kathy Glass and Kirsten Englund

Throughout the stormy "whale wars" of the last 15 years, Japan has remained an island of determination in a sea of opposition. Japanese whalers in Antarctic waters were to take up to 300 minke whales for research purposes in the 1988/89 season. For many environmentalists, this insistence on whaling is insupportable, and the Japanese are easily vilified in history's most widely publicized conservation campaign.

Japanese attitudes toward whaling, however, have been perhaps the most neglected aspect of the controversy as reported in the United States. Although such a long-running dispute demands the effort to learn why the opposition thinks and acts as it does, there is surprisingly little movement in this direction on either side. Cultural gulfs can divide people more than any ocean.

Japan is one of the strongest opponents of the International Whaling Commission (IWC) moratorium on commercial whaling; the United States is its main proponent. Scientists from both nations can produce research that supports their countries' positions. How do public opinion and the histories of whaling in each nation fit in? A comparison of attitudes and cultural contexts in Japan and America sheds some light on the issue.

As two American environmentalists living in Japan, we've had good opportunity for such comparison. Maybe we've been here too long, but the clean line that U.S. activists draw between right and wrong has become blurred for us. A larger context seems necessary to fully understand the issue and to develop a more effective approach to "saving the whales." This approach begins with an attempt to comprehend—and respect—the Japanese.

Traditional Whaling

At Taiji, a remote Japanese whaling village with an excellent *kujira-kan* (whale museum), we started to think about whaling in another light—and another age. A fascinating picture unfolds. The historic roots of Japanese whaling are a large part of current Japanese attitudes, yet this impressive tradition is virtually unheard-of in America where the focus is on the atrocities of modern whaling.

Various forms of whale meat are sold at the Kyoto fish market, including this "bacon," a mixture of meat and fat. (Photo by Clark Bortree)

Traditional net whaling, as developed in Taiji about 1606, required both manpower and courage. Whaling crews 300 strong responded to the signal flags of lookouts posted on steep cliffs by launching teams of small oar-driven boats, each with a different function. The lacquered and brightly painted chase boats carried the harpooners and were possibly the fastest human-powered boats anywhere at any time. The net boats carried large-mesh nets with barrels and baskets attached to slowly ensnare and tire a whale journeying along the coast. Capture could take hours before the exhausted whale rolled slowly

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A Shinto priest purifies whaling knives in Tada Shrine, 1981. (Photos in this article courtesy of Japan Whaling Association unless otherwise noted)

on the surface, tangled in nets and harpoon lines.

At this point a boy with a knife would dive in, risking entanglement in the nets and an encounter with sharks often attracted to the scene. Grabbing the nets, he would scramble toward the blowhole, plunge his knife into the whale's septum, and hold tight as the frantic animal made one last dive. Then the carry boats would move into position to secure the whale for the long journey home.

Back in Taiji, word of the sighting would be out, and a processing team of 250 to 400 people on the beach would prepare to work, celebrate, and secure prime cuts of tail meat. The day's heroes would be honored and rituals performed for the whale's soul and the town's good fortune. Such was the way of life for centuries.

In the heyday of Taiji's net-whaling operation, "a whale on the beach meant wealth for seven villages." During Japan's feudal Tokugawa period, entire coastal regions relied on the myriad resources supplied by whales. All parts of the animal were used ingeniously for food, fertilizers, oil, and other products.

But now the Taiji beaches are deserted and the economy depressed, despite efforts to attract tourists. The town's identity and solidarity, once maintained by its strong whaling culture, are fading. There is bitterness toward those who are forcing an end to whaling. Despite the international pressure, Japanese whaling families still consider themselves to be engaged in a proud occupation. To them the views of the opposition are incomprehensible.

Whales in Japanese Culture

Some Americans might be surprised to learn that Japanese, particularly in whaling communities, have always had great respect for whales ("Buddha and the Whale," pp. 52–53). In contrast

A tombstone honoring spirits of harvested whales.

to the once common American whalers' practice of aiming for a calf to catch the adults who rushed to its aid, the killing of females with young was forbidden by the Japanese since the early days of net whaling. Whales are honored in Buddhist and Shinto memorial rites; whale monuments and "gravestones" are scattered throughout Japan; and some whalers still pray for the soul of each whale killed.

However, Japanese respect for the whales they hunt doesn't translate into what Americans understand as reverence. The Western perception of whales as intelligent, beautiful, and spiritual is considered sentimental and irrational by many Japanese. Buddhists consider all animals to be equal, and Japanese do not hold whale intelligence in high esteem, partly because they have not been as exposed to behavioral research or oceanarium shows as most Americans have.

In Japan it is not contradictory to regard animals as sacred and also to kill them for food. A 1489 cookbook reveals that whale meat has been eaten in Japan for at least 500 years. Japanese have historically depended on the sea, and the sense of whales as a resource similar to fish lingers in the Japanese psyche, evident in the character for "whale," which includes the radical for "fish."

During the food shortage after World War II, whaling was encouraged by U.S. occupation forces, and whale meat constituted 47 percent of the meat supply. Many older people today cherish the flavor of whale meat because it has the taste of survival. Whale continued to be a major

source of animal protein until the mid-1960s, popular in school lunch programs. Now beef, chicken, and pork have surpassed whale in availability, affordability, and for many, desirability. Japanese today enjoy every kind of imported food and strictly speaking, whale meat is not essential.

Many people do cook certain dishes with *koro* (dried whale fat), and whale *sashimi* (raw whale meat) is an expensive delicacy for urban Japanese. In a few coastal areas there is a distinctive local cuisine based on whale meat that is an important part of special occasions such as marriage and New Year's feasts. These communities are most affected by the declining supply. While many other Japanese are ambivalent about whale meat, there does seem to be a consensus that if whale hunting doesn't threaten extinction, there's no reason why the meat can't be consumed by those who want to.

This feeling merges with nationalism in people who resent being told what to do and want to preserve whaling as part of Japanese culture. Antiwhaling rhetoric about the "cold-blooded" or "barbaric" Japanese prompts editorials claiming, for example, "an unfounded anti-Japanese sentiment at the root of the world's antiwhaling mood." Some Japanese believe the rest of the world, and particularly the United States, envies Japan's economic success and uses the whaling issue as an outlet for frustration.

Charges of cultural imperialism are based on the conviction of Japanese scientists, intellectuals, and politicians that limited whaling will not endanger the particular species they want to hunt. They note that the Scientific Committee of the IWC has never considered the current blanket moratorium necessary; it was voted into effect by pressure from environmentalists. The Japanese advocate returning to the IWC policy of species-by-species management, resuming controlled minke whale hunts in the Antarctic, and continuing coastal whaling of nonendangered species. There are efforts within the IWC to establish a new category legitimizing small-scale coastal whaling for minke and sperm whales as culturally important, albeit "commercial." Japan also is carrying out research whaling to prove the feasibility of taking at least 3,000 minkes annually from an estimated (and disputed) 690,000 in Antarctic waters.

Modern Japanese Whaling

Japan's last pelagic whaling enterprise was dissolved in November, 1987, to comply with the IWC, but this same "fleet" (a rusty old mother ship and two catcher boats) has been sent to the Antarctic for the last two seasons. The take was 273 minkes in 1987/88 and is not to exceed 300 in 1988/89. While admittedly an industry study for future utilization, and a means of "keeping the oar in," the expeditions are not commercial whaling in disguise, since the small takes are vastly unprofitable—even with a government subsidy, private donations, and sales of the meat.

Centuries old ceremonial whale dances are still performed around replicas of traditional vessels.

Accused by antiwhaling activists of violating an international convention by research whaling, Japan is technically within IWC rules allowing member governments to issue permits for such hunts. In fact, the moratorium passed by the IWC in 1982 included a provision to make a comprehensive assessment of whale stocks by 1990. The Japanese consider their studies of reproductive capacity and natural mortality of minke whales in the Antarctic to be contributions to this assessment.

The Japanese also maintain a small-scale coastal whaling industry for small cetaceans not under the jurisdiction of the IWC, such as pilot and Baird's beaked whales. There are nine whaling boats of less than 50 tons, with crews of five to eight men each. Although the technology has changed over the centuries, this type of whaling does have validity as a cultural tradition. (Pelagic whaling, on the other hand, dates only to 1934.)

Today there are four communities where whaling is the binding social and/or economic force—Taiji, Ayukawa, Wadaura, and Abashiri. An end to coastal whaling will mean the direct loss of about 100 whalers' jobs and adverse effects on all involved in the processing and distribution network. Customs, culinary traditions, and festivals centered on whaling will become meaningless and eventually disappear. Village populations are dwindling now, and the problem of maintaining traditional life in a local place looms large.

For Americans who frequently change jobs, habits, and homes, tradition may not mean much. This is one way they fail to understand the Japanese, whose society is built on life-long employment and maintenance of family, community, and national traditions. Changing jobs in midcareer is not easy or common.

Most Japanese with little at stake in the whaling issue sympathize with this loss of jobs and purpose among whalers. Prowhaling propaganda charges that foreign environmentalists have no compassion for people who depend on whales culturally and economically. Today's coastal whaling of nonendangered species (less than 400 whales a year) sustains both whale populations and a unique human culture—one in many ways more conducive to community bonds than urban Japanese existence.

American Whaling

The United States position on whaling is made particularly untenable to the Japanese by the fact that Alaskan Inuit hunts of the endangered bowhead whale (article, pp. 54–62) are condoned as subsistence (not commercial) by the United States and the IWC. The current quota is 41 from an estimated population of 7,800. Japanese whalers claim whaling is just as vital to their communities as to the Inuit. In the Japanese view, the criteria for catch allowance should not be whether whaling is commercially operated, but whether the target species is endangered. Allowing bowhead hunts makes the U.S. posture toward Japan appear inconsistent with a genuine concern for conservation.

Since its relatively recent surge to power, the emotionally charged antiwhaling mood in America has, in fact, been a puzzle to Japanese. The United States didn't completely abandon whaling until 1971. Japanese critics of the American position note that the protectionist view has only been able to flourish in the absence of any direct U.S. economic interest in whaling.

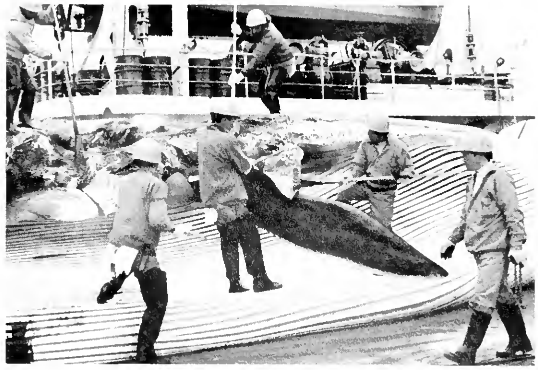
According to some Japanese observers, the fervor with which Americans embraced the "Save the Whales" movement seems to have produced a certain amnesia in regard to the U.S. whaling tradition. Few American activists acknowledge their own nation's lamentable history of whaling, with its shallow cultural roots and strong economic motives. The waste inherent in the Western pursuit of whale oil, not meat, appalls the Japanese. In fact, Japanese seem to know more about U.S. whaling than does the average American: It was the West that taught Japan the most lethal methods of killing whales, and the desire of wide-ranging American whalers for a foreign port contributed to Perry's historic 1853 mission to pry open Japan's doors.

The Japanese charge that conservation groups too often project a single image of whales—for example, the majestic blue whale, hunted ruthlessly to a point from which it may never recover. Americans who respond to desperate appeals for protection may not be aware that there are many kinds of whales—some endangered, some not—and that great strides toward protection have already been made. The most productive tactics for raising "whale consciousness" and donations tend to be seen by Japanese as hysterical.

Backed into a Cultural Corner

Lacking respect for the perceived irrationality of environmentalists, and bristling at insults construed as racist, the Japanese have been backed into a cultural corner. At stake are Japanese tradition and pride. While many Japanese are resigned to the end of whaling, conservatives object loudly to "cultural domination" and strong-arm political maneuvers such as trade sanctions by foreign governments (*Oceanus*, Vol. 28, No. 3, pp. 76–79). Influential

Developed in the 17th century, traditional Japanese whaling required manpower and courage.



At left, hauling a fin whale onto a factory ship and flensing it, above. The only remaining Japanese factory ship is used for research whaling.

conservatives within the Japanese government are the people permitting and funding research whaling. They also influence the media to heighten public feelings of nationalism and empathy with the whalers' plight.

Nationalist propaganda reveals not only the pride inherent in the "official" Japanese attitude toward whaling, but also the fact that most Japanese simply don't understand the environmental consciousness that fuels antiwhaling sentiment. This basic cultural gap is the main cause of the controversy.

Environmental Education

The widespread opposition to whaling in America is part of a larger environmental movement that unfortunately has no effective parallel in Japan. Whale-watching expeditions, Sea World, TV documentaries, and Greenpeace mailers are part of American life, and the availability of environmental education material in the United States far exceeds that in Japan. Also, the act of protesting government and big-business practices is not as established in Japan as in the United States. "Remember, democracy is an import," a Japanese environmentalist notes. "People here aren't as quick to denounce authority and tradition."

Confrontational tactics are actually counterproductive inside Japan. They spur negative coverage and add fuel to prowhaling propaganda. Some Japanese sympathetic to an antiwhaling position are reluctant to be associated with Greenpeace. In this society, confrontations simply are not viewed with respect, regardless of motive.

Until recently there has been little opportunity for a "Save the Whales" movement to emerge in Japan. However, this is a good time for subtle persuasion. Japanese attitudes toward whales are slowly changing under circumstances similar to those that contributed to the American passion for whale conservation. "Safari parks" and oceanariums are more popular than ever, and now often include live dolphin and killer whale shows. This is having an impact on young Japanese as they learn first-hand about the intelligence of these animals.

Japan's first whale-watching cruise took place in April, 1988, off the Bonin Islands south of Tokyo, with more cruises planned for the future. The reconstruction of authentic Taiji-style chase boats may enable a unique form of whale-watching off Shikoku in the summer of 1989, while also preserving traditional boat-building knowledge. There is also potential for the growth of modern behavior-oriented whale research, such as the identification of markings and voices. Japanese and Canadian scientists are currently working together in Japan's first such noninvasive study.

Increased education about marine mammals and the creation of a nonlethal whale industry like the very profitable one in America (whale-watching and the various forms of "whale art," for example) will allow Japanese traditions to be altered in positive ways from the inside. Encouraging these activities may be more productive now for antiwhaling forces than the usual high-pressure tactics and confrontations.

Until the Japanese can truly understand the attitude of those who believe deeply enough to risk their lives to save whales, they will continue to perceive demands for an end to whaling as a culturally biased imposition of ethics. And they will continue to insist, not unreasonably, that ethical and scientific aspects of the whaling issue be separated, with decisions

based only on scientific findings.

But utilization-minded and conservation-oriented scientists speak different languages. The Japanese talk statistics: If there's a large number of whales, hunting a few poses no problem. On the other hand, scientists opposed to whaling take a wide variety of factors into account, such as the complex structure of whale groupings and activity, and the problem of ongoing habitat destruction. Much of the case against commercial whaling rests on the fear of still-unknown effects of hunting, even in populations thought to be increasing, such as southern hemisphere minke whales.

Nonetheless, there is very little agreement

Restaurants specializing in whale meat cuisine are popular in urban Japan. (The Bettmann Archive)

within the IWC on actual population figures. Presumably the IWC's comprehensive assessment of whale stocks to be carried out during the moratorium will yield less disputed figures or else prove we can't be sure of anything. But if Japanese research is debunked in 1990 without compelling evidence to the contrary, Japan claims it will have no reason to remain in the IWC. The Japanese are frustrated with the unfocused nature of the commission, which was established to regulate resource use and now takes a totally protectionist position.

Politics and science control most IWC activity, but the cultural aspect of Japanese whaling is given little consideration. Westerners have difficulty identifying the modern, prosperous nation as one that clings to old ways. Yet it is the people's demand for whale meat—a cultural need—which keeps the industry alive. The Japanese market supports other nations' whaling industries, as well as most illegal whaling. Although consumption of whale meat is declining as the population ages and coastal whaling becomes more and more anachronistic, whaling will probably continue in one form or another until this demand subsides altogether and environmental awareness grows among Japanese.

The IWC moratorium was a victory for environmentalists, but its effectiveness can be debated. "Pirate" whaling is fueled by a decreased supply of whale meat, and with these operations endangered species can be taken and no research data accrues. Whaling has traditionally been the main source of information on whales, and member nations of the IWC have spent decades creating a scientific whaling industry. In the absence of controlled commercial ventures, cetacean research becomes almost prohibitively expensive. In Japan, for example, there is no network of environmental groups to help fund noninvasive behavioral studies. Thus, a moratorium is not a quick fix. Ending whaling for good will take time.

Poor Track Records

The insistence on a whaling moratorium is largely a backlash to the earlier mismanagement and abuse of whale stocks. Through the 1960s and '70s, Japanese representatives to the IWC repeatedly proposed unsustainable quotas, and Japan has yet to convince conservationists that it can responsibly handle a resumption of whaling. Pirate whaling and a fishing fleet notorious for violations impair Japan's international image considerably. Japan's poor reputation in environmental circles is largely deserved, not only in regard to whaling. Conservation consistently takes a back seat to development, both at home and abroad.

Of course, virtually every other nation is involved in various marine wildlife offenses; Japan has no corner on that market. The fact that the entire ocean is mismanaged and facing irreversible habitat damage is often overlooked in the zeal to shut down the whalers. If half the outrage over Japan's research whaling were focused on larger issues such as offshore oil drilling or toxic waste disposal, the whales' cause might be better served.

A public image prevails in the West, of Japan as a proud and stubborn whaling nation. But it's important to realize there is more than one Japanese attitude toward whaling, and Americans can support and encourage the more ecologically minded. Many Japanese, sensitive to international opinion, advocate an end to whaling to raise Japan's status among environmentalists. Others claim continued whaling isn't worth U.S. sanctions against the fishing industry. And some feel, as many Americans do, that it's high time to strike a better ecological balance, regardless of sacrifices for humans.

Many people in and outside Japan consider pelagic whaling economically doomed. Small-scale coastal whaling will probably keep on somehow, despite declining catch quotas. But with the future of whaling dim and city lights bright, fewer young people have the dream of pursuing their family's occupation. The current generation of whalers will probably be the last to

put up a good fight.

In view of the natural decline of the industry and the progress already made in controlling the whale slaughter, we believe a supportive approach to fostering environmental awareness in Japan is the best direction the antiwhaling movement could take now. And we would agree if the IWC acknowledged the cultural validity and limited impact of small-type coastal whaling, and continued to ban pelagic whaling for profit alone. It's important to tolerate a cultural tradition different from one's own, and to see that any moral stand—no matter how righteous—is necessarily relative.

Cultural Awareness

Perhaps most illuminating for us has been the realization of how culturally determined are our own views toward whales. Economic and cultural attachment to whale products have been negligible in the United States and virtually nil among younger generations. On the other hand, environmental concerns play a significant role in the formation of our values. This situation is reversed in Japan. Although whales are a symbol in the West of everything wrong with the relation of people to the planet, there's no reason to expect the Japanese to see whales in the same way.

In the desperate attempt to forestall environmental catastrophe, we activists have had to simplify issues and demand immediate sweeping changes. We feel keenly our responsibility to the earth. Yet we also have a responsibility to see the limits of our tactics when practiced in relation to other cultures. It seems probable that Americans could relate better to the Japanese, subtly encouraging their environmental awareness and not alienating them and their traditions. Likewise, the Japanese could better understand why conservationists crusade as they do. Ultimately there is more at stake than whales, and forcing the Japanese to abandon a tradition for reasons they cannot understand would be a hollow victory. □

Suggested readings

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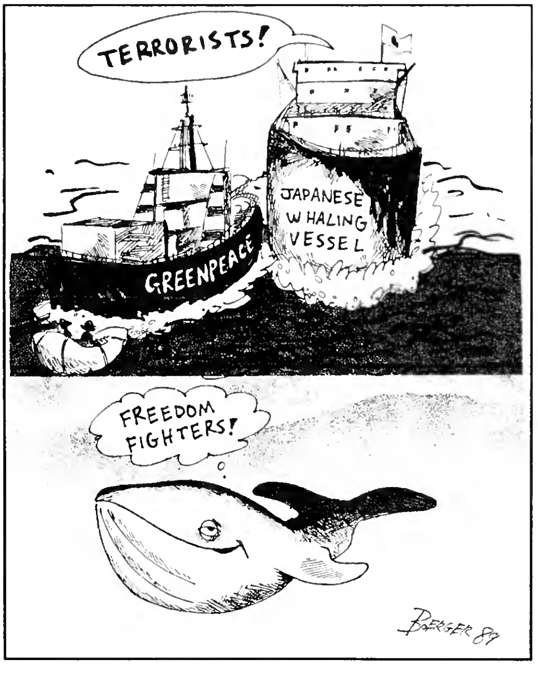


Courtesy of The Daily Yomiuri

Buddha and the Whale

Many Japanese believe that whales have souls. In many whaling communities, individual whales are given a marker or gravestone at a particular shrine or temple. To celebrate whale harvests, Buddhist and sometimes Shinto rites are held, often at set times of the year, such as the spring or autumn equinoxes, or during the All Souls' Festival held in the eighth month of the lunar calendar. These rites are similar to the Japanese memorial rituals that stress ancestor worship.

The Japanese attribute souls to both animals and objects—specifically, to those that have been of some use, have been harmed, or have come to the end of their usefulness. This is very different from the Western Judaeo-Christian concept of soul, which is often equated with mind or reason and restricted to humans (even though anthropomorphism is widely evident, from Moby-Dick to Mickey Mouse). Whaling also plays a large social role in the communities where it is practiced.

The Japanese attitude toward whales runs counter to the traditional Western image of heartless, yen-seeking harpooners aiming their cannons at defenseless, endangered animals—a seed sown by well-intentioned environmental organizations such as Greenpeace. A more balanced picture emerges from the report of an international workshop on small-type coastal whaling in Japan, held in 1988 by the Japan Social Sciences Association Fund to Promote International Educational Exchange and the Boreal Institute for Northern Studies, both located at the University of Alberta in Edmonton, Canada.

The question raised by the report is, if small-scale whaling by aboriginal societies is allowed on the basis of social, nutritional, religious, and local-level economic importance, why not allow small-type coastal whaling as well?

Religious Traditions

The major religions in Japan are Buddhism and Shinto. Christianity has never claimed much more than one percent of the total population of about 121 million, living in an archipelago with about the land area of California. Many Japanese keep Buddhist and Shinto shrines in their homes. Indeed, it is common custom today for Japanese to be born with Shinto rites, have a Christian wedding, and be buried in the Buddhist tradition.

Although there are significant local variations in the performance of whale memorial rites, for the most part, they employ common religious themes that are based on a unified view of the interdependence of human and animal worlds. For example, the Kannonji temple in Ayukawa houses two altars, a large one for Buddhist divinities and a smaller, secondary altar for spirits of the dead. This latter altar has tablets for deceased persons, tablets especially for fishermen and whalers who have died at sea, and three tablets for the souls of whales.

The tablets for whales, all commissioned at considerable expense by whaling communities, and standing about 15 inches high, are the subject of daily prayers. On the occasion of annual memorial rites, the tablets are taken down to the beach and placed on a temporary altar. Elaborate offerings of flowers and vegetables are presented to the whales. Prayers express the community's collective repentence for the unavoidable sacrifice of human and animal life involved in subsistence.

Feeding the Hungry Ghosts

Whales and whalers who have died at sea are called "hungry ghosts" and the Buddhist rites are for "feeding the hungry ghosts." In some cases, memorial rites tablets are made from wood, but there are also stone pillars and markers, often where whales are actually buried. Many temples and shrines have death registers for whales, called *kakochō*.

In some memorial ceremonies, lamps representing the souls of whales are floated out to sea as a subsidiary rite. This practice, according to the report, is based on the notion that the world of the ancestors exists out beyond the sea, and that whale souls are bound for this other world.

The memorial rites and whale festivals, such as those at the town of Taiji, become occasions to express concern about the moratorium "and to reaffirm the local commitment to continued whaling." In January, at the Asuka shrine (temples are Buddhist, shrines Shinto) in Taniji, an archery festival features three wooden models of right whales. "After the archery, the Shinto priests throw the whale models into the crowd. Whalers rush to catch them and take them to their whaling boat where they are placed in a small shrine on board for good luck."

The research that forms the basis of the international workshop report was carried out in each of the four small-type whaling communities in Japan by a team of experienced anthropologists and one sociologist. The researchers interviewed whaling crews, flensing station workers, whale meat distributors and processors, merchants, priests, municipal government officials, town historians and museum curators, housewives, and others.

The harpooner, being the one person most directly involved in killing whales, prays both at sea and on land for the souls of his prey. At sea, he makes an offering (usually a piece of tail fin) at the shrine on the boat and later on land. In Ayukawa, the harpooners gather once a year to set the date for the memorial service for the whales they have killed. A Buddhist priest in the town commented: "Harpooners have stronger

beliefs in the gods and Buddha than others on the boats . . . . Some express the depth of feeling they have in killing the whale; they all feel deeply about killing any living animal . . . ."

At the beginning of the whaling season in another town, a Shinto priest purifies the boat as well as the whalers so that they are pure enough to be accepted by the gods. "The priest places a paper charm on an altar on the boat in order that the boat and whalers will be protected and blessed with a good harvest. The whalers offer sprigs of a tree, and salt, rice, and water," the report states. Once whaling starts, the whalers and their wives worship the gods and Buddha at home as well as on the boat.

The communities at large contribute to the whale worship as well, ranging from temple parishioners who help sponsor the memorial services and tablets to general households who contribute food and funds for the festivals. Thus, the whale is firmly entrenched in the religious and festive lives of the villagers.

The Gift of Whale Meat

Gift-giving is a deeply rooted part of Japanese society. Friends and business associates commonly exchange gifts during the New Year holidays. In whaling communities this includes whale meat. The gifts can reflect rewards for duties performed (distribution of the meat, for example), or the return of gifts received (say, on the launching of a new boat).

The exchanges involve a large number of people who live in the whaling community and who may be only peripherally connected with whaling, such as the fishermen who report whale sightings to whalers or elderly people who work in the flensing factories.

Between the start of the whale season and the first whale harvest, gifts known as *omiki* are presented to vessel owners, individual crew members, and the vessels themselves. These gifts are mostly in the form of sake, rice wine that has important ritual connotations in Japanese culture. As many as 1,500 bottles of sake are estimated to have been sold in one community during the April first-catch gift-giving celebrations, representing about 80 percent of the annual sales of the town's seven wine dealers.

It is customary for a boat owner to return at least one kilogram of whale meat to each person from whom he has received sake, whiskey, beer, or Coca-Cola, the latter three being encouraged by the owner who has trouble consuming large amounts of the wine. The retail price of first grade sake is just under 2,000 yen, or about $15 a bottle. The majority of gifts consist of two bottles.

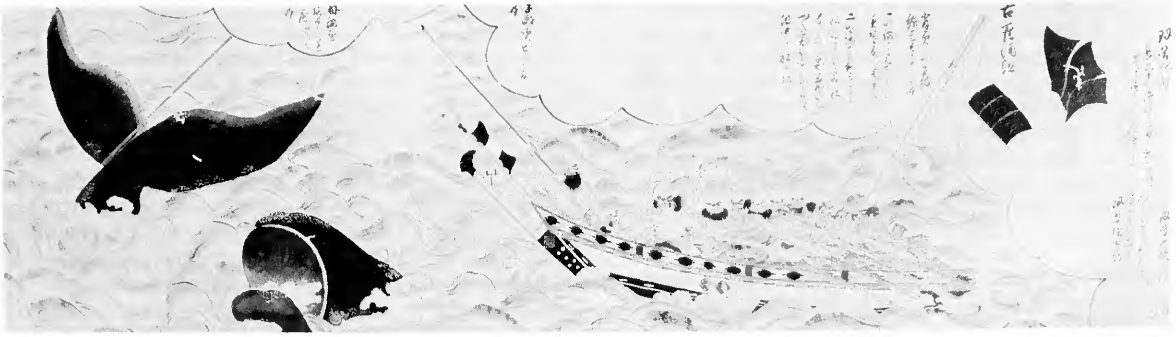
The crews of the boats receive sake as gifts continuously throughout the year and receive between 30 and 40 kilograms of whale meat to reciprocate gifts. Each boat has about 50 bottles of sake or its equivalent on board at any one time.

Gifts of large amounts of whale meat are made to the local community centers and in turn distributed to old people's clubs, schools, hospitals, and so on. The local people say that "fish is to be purchased, whale is to be received."

Japanese government officials are trying to promote tourism as an alternative for villagers deprived of a living and their traditional whaling customs. But as one villager put it: "Look at this place. A couple of crummy ships, a. . .ferry boat pier, and that's it. Tourists come here to have a bit of sushi, take a leak in the public toilet there, and drive off. That's tourism in Ayukawa. That's our future."

A Japanese woman who runs an inn in one of the communities summed up the situation: "My father came here 80 years ago with the start of whaling and we have lived by whaling, and that's why I'm concerned about this [moratorium]. I'm about to die and this town is about to die. . .the town lives by the whale. The whale is our life."

—Paul R. Ryan
Editor, *Oceanus*
On Fellowship in Japan



This scroll depicts a small-type coastal bowhead whaling operation. (Courtesy of Japan Whaling Association)

A long and controversial relationship

Eskimos, Yankees, and Bowheads

by Howard W. Braham

Eskimo whalers with their umiak about to set out for the "big fish," circa 1900. (The Bettmann Archive)

The Eskimos who live along the coast and on islands of northern and western Alaska are renowned for their skill at hunting mammals from the sea. Among the creatures they pursue are the walrus (*Odobenus rosmarus*), the ringed seal (*Phoca hispida*), the bearded seal (*Erignathus barbatus*), the polar bear (*Ursus maritimus*), and the beluga whale (*Delphinapterus leucas*). But prized above all other species among the Inupiat- and Yupik-speaking people of this region is the bowhead whale, *Balaena mysticetus*.

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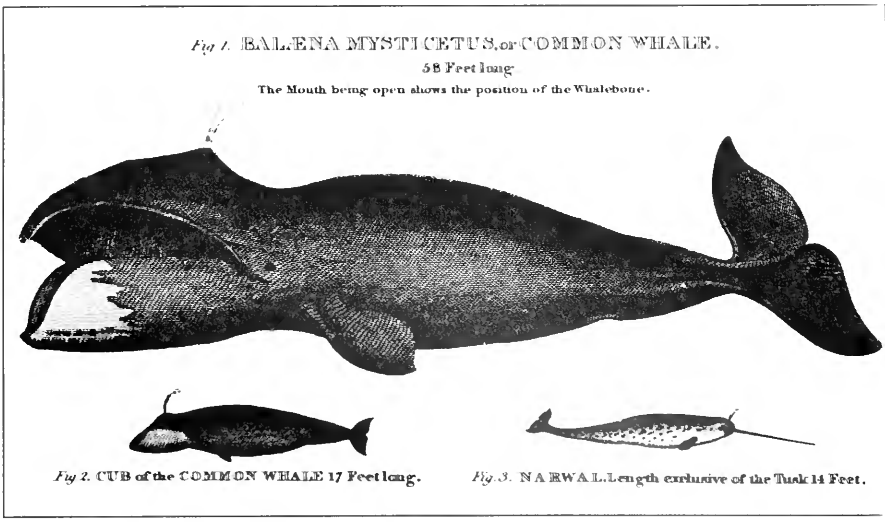
It is also a species that has attracted the attention of marine biologists, to say nothing of conservationists and the larger animal-loving public. Many of them consider the bowhead highly endangered, with a population only a small fraction of what it was a century ago. So the question arises: Is the continued hunt by the Eskimos, as limited as it may be, threatening the bowhead's survival?

This question has been central to my work as a biologist for the last decade. But before I even attempt an answer, it's important to explore the long, complex, and lately highly controversial relationship (in the eyes of outsiders, not the Eskimos themselves) between the hunter and the hunted. As late as the mid-1970s, when I was

beginning my studies of bowhead and gray whales, *Eschrichtius robustus*, many Inuit* whalers were still calling it the black whale, or just the whale, the latter a translation of their native words *ahvik* or *agvik*. The nomenclature made perfect sense to the Eskimos. Except for an occasional beluga, the bowhead is the only whale most of them ever hunt.

And this has apparently been so for millennia. Old whaling culture artifacts, including harpoon and lance blades as well as bowhead bones found east of the village of Kivalina have been radiocarbon-dated back to 1800 and 1500 B.C. We can thus conclude that ancient hunters, perhaps ancestors of today's Eskimo hunters, were probably pursuing bowhead whales among the ice floes of the eastern Chukchi Sea as long as 4,000 years ago, although it's possible that they may have simply butchered naturally stranded whales. Curiously, the old whaling culture appears to have had no known antecedents, and vanishes almost as quickly as it emerged from the archaeological record.

Hence we can't really affirm an unbroken cultural continuity between the traditions of these ancient people and modern Eskimos. Even so, the evidence suggests that in this region of the Arctic, the bowhead whale has long been part of Eskimo life. Today, we still see remnants of very old traditions preserved in some of the



An 1820 print by naturalist William Scoresby showing bowheads and a narwhal.

* Many Natives prefer to be called Inuit rather than Eskimos because the latter is a name introduced by whites meaning literally "eater of raw flesh" in the aboriginal language.

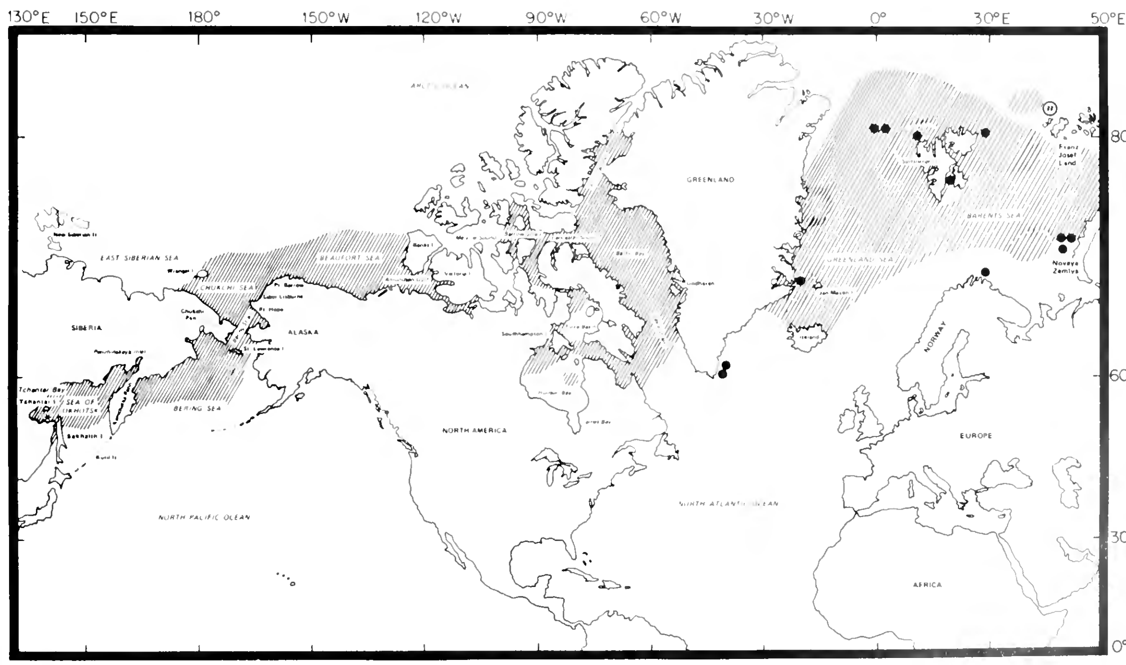


Figure 1. Presumed historic distribution of bowhead whales. Five putative stocks are the East Greenland; Davis Strait-Baffin Bay; Hudson Bay-Foxe Basin; Sea of Okhotsk; and Bering, Chukchi, and Beaufort Seas, or the Western Arctic stock. Only the Western Arctic stock is considered healthy, and appears to be increasing.

ceremonials of the hunt (book review, pp. 137–139). And it's this venerable relationship between hunter and whale that underlies the insistence of Alaskan Eskimos that taking "the whale" is a part of their heritage that should not be denied them.

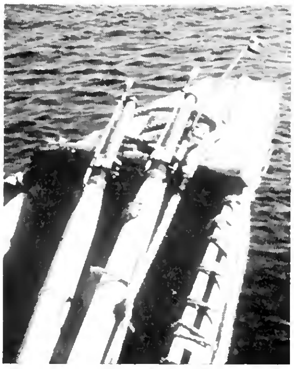
By contrast, Europe's interest in the bowhead is much more recent. Seventeenth-century European whalers, hunting the bowhead off east Greenland and Spitsbergen, called it the Greenland right whale, or common whale, confusing it with its close cousin, the northern right whale, *Eubalaena glacialis*. The term bowhead apparently was first widely used by Yankee whalers. It presumably stems from the bow of its huge, arched mouth, the repository of its long, highly valued plates of baleen, or whalebone—although some authorities variously attribute the name to the head's resemblance to a ship's bow or the similarity in the bending of the baleen to an archer's bow.

Back to the Historic Records

Scientists believe that there are at least four, or more likely five, geographically separate populations, or "stocks," of bowhead whales worldwide. All live in the northern hemisphere, and are associated with ice-bound regions of Arctic and Subarctic waters (Figure 1). There were perhaps 55,000 or 65,000 bowhead whales before commercial whaling began; today there are probably only 6,000 to 12,000 (Table 1).

Estimates of the earliest populations are based on fragmentary information from old whaling logbooks. The method is labor intensive and requires the would-be census-taker to sort out whale species from records that are not only occasionally inaccurate about the types of whales caught but also often combined with catch data recorded either as barrels of oil or as the weight of whalebone. Still, as imprecise as the technique may seem, a dramatic picture has emerged of the magnitude of the takes and how quickly early commercial whalers raced through each population, one after another.

A hunting party brings home a whale (top), killed with traditional darting "iron" (right). Opposite page: villagers join in the job of hauling ashore and flensing the prize. (Photos of hunt by David Withrow, National Marine Mammal Laboratory; darting irons by Willman Marquette)



European whalers began working the eastern North Atlantic about 1610. In barely a century they had so reduced the whale population that they were compelled to seek out more lucrative whaling grounds in Davis Strait, between Greenland and Baffin Island. By the middle of the 19th century, Yankee whalers discovered bowheads in the North Pacific and Western Arctic, first in the Sea of Okhotsk, then in the Bering, Chukchi, and Beaufort Seas. The effect of the take of bowheads in the Western Arctic was even more dramatic than in the North Atlantic (Figure 2). In less than 20 years, more than 60 percent of the bowhead population was gone. By 1915, more than 18,000 bowhead whales had been killed in the 65 or 70 years of the fishery.

The Yankee whalers also had an impact on the traditional Eskimo hunt. Until the 1870s, Alaskan Eskimos hunted bowheads using only the primitive implements of their forefathers: eight-foot wooden harpoons with a bone toggle head and a sharpened slate tip. Then, under the influence of Yankee whaling technology, the Eskimos began using black powder bombs, which were fired into the whales. The explosives vastly improved the efficiency of the hunt.

The two weapons used to launch the

explosives were also passed on by the Yankee whalers: the shoulder gun, circa 1870, and the darting gun, or "iron." The latter consists of a two- to six-foot iron harpoon, mounted on a heavy wooden throwing shaft, about six feet long. The harpoon is fixed with a metal toggle tip (point) and a simple triggering device. The latter discharges a 14-inch brass tube bomb, equipped with a time fuse that can be set to explode after the bomb penetrates the whale's thick layer of blubber. (Other than being four inches shorter, the darting gun's bomb is almost identical to the one used in the shoulder gun.) The barrel for the bomb is near the tip of the shaft, with the harpoon and trigger affixed on either side. A sealskin float (or "poke"), or more recently, a plastic fishing float, is attached to the harpoon shaft with a few hundred feet of rope, which

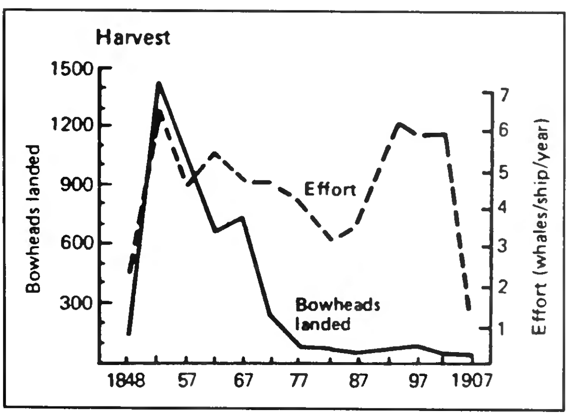


Figure 2. Historic takes of bowhead whales in the Western Arctic. Note dramatic decline in catches while whaling effort (number of whales per ship per year) remained high. The increase in effort around 1880 reflects a change to the use of ships with auxiliary engines from ships driven by wind alone.

quickly uncoils after the whale is hit. The float helps restrain the wounded whale, slowing its movements.

The shoulder gun is a solid brass smoothbore firearm similar to a large-bore sawed-off rifle. Black powder is still in use, but is being replaced by an explosive called Penthrite, which the hunters hope will be more dependable. This switch was encouraged by the often premature explosion of black powder and the frequent failure of the bomb to explode once inside the whale. Instrumental in the bomb's redesign were the whalers themselves, with the help of Norwegian explosives manufacturers and funding by the North Slope Borough (the regional government for the northern Alaska communities), the National Oceanic and Atmospheric Administration (NOAA), through a grant to the Alaskan Eskimo Whaling Commission, and the State of Alaska.

A Small but Sustained Hunt

The hunting of bowheads by the Eskimos has been small but sustained, involving the inhabitants of small villages along the coast of Alaska, Canada, and the far eastern Soviet Union. No active bowhead whaling has occurred in Canada

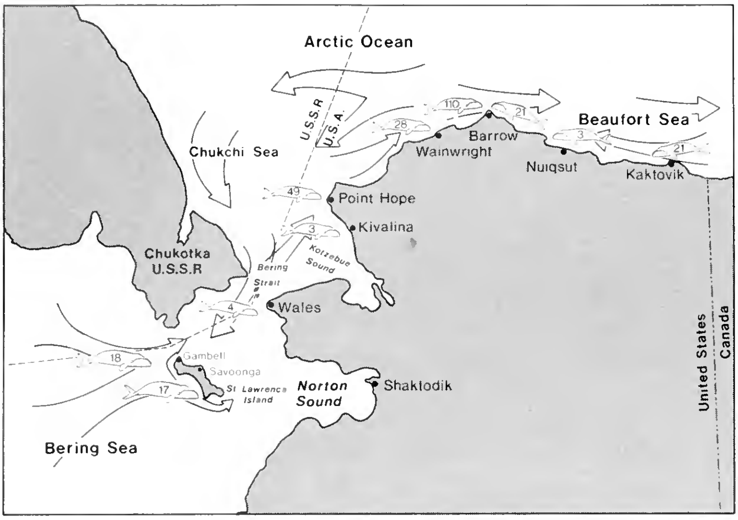


Figure 3. Alaskan Eskimo coastal villages actively engaged in bowhead whaling. Numbers in bowheads are total whales landed since 1973. The direction of the whale reflects the direction of the seasonal migration and the season whales are taken; right = spring hunt, left = autumn hunt.

or the Soviet Union this decade, however. Settlements now active in the taking of bowheads in Alaska are Gambell and Savoonga on St. Lawrence Island in the Bering Sea, Wales at the Bering Strait, Kivalina, Point Hope, Wainwright, and Barrow along the west coast of the Chukchi Sea, and Nuiqsut and Kaktovik along the north slope of the Beaufort Sea (Figure 3). Spring whaling in the open water corridors, or "leads" in the pack-ice, are conducted at all settlements but Nuiqsut and Kaktovik, where the hunt takes place in autumn. Barrow is the only village that participates in both a spring and autumn hunt.

Traditionally, most of the whale was used—for food; for making weapons, fishing lines, traps, tools, and objects of trade or barter; for constructing homes or cold storage houses; for heating and cooking; for toys and baskets (many of which are now collector's items); and for many other practical day-to-day uses. Those parts that weren't eaten, such as the lungs and liver, were fed to the ubiquitous sled dogs.

However, since the late-19th century when whalers and traders invaded the north, the Eskimos have turned increasingly to imported substitutes for many of these whale products. And the trusty whale-eating sled dogs have now been all but replaced by gasoline-guzzling snowmobiles—or snow machines, as they're called in the north country. Still, even today, the bowhead is an important source of vitamins and protein, and for the Eskimos the slices of skin and blubber known as muktuk, eaten either raw or boiled in salted water, remain a favorite treat. In addition, whale oil continues to be used for fuel and cooking, and out of the bowhead's abundant supply of baleen, those Eskimos with a gift for handicraft make such products as baskets or model sailing whaleboats. Occasionally a single baleen plate with a crafted design is sold as "native art."

Across the Bering Sea, along the Chukotka Peninsula in the Soviet Union, Eskimos once stalked the bowhead in the same traditional manner as the Alaskan Inuits. But there too life has changed drastically in this century. The Chukot Eskimos no longer engage in the hunting of bowheads because it's banned under an agreement between the Soviet Union and the International Whaling Commission (IWC). Instead they have turned to gray whales, whose numbers have fully recovered in recent years. Under an

Table 1. Estimates of abundance of the world's stocks of bowhead whales.

	Population Size			
	Initial[1]		Current	
Stocks	**Year**	**Estimate**	**Year**	**Estimate**
East Greenland	1679	25,000	1980	Unknown[2]
Davis Strait	1825	11,000	1981	Unknown[2]
Hudson Bay	1859	680	1981	Unknown[2]
Sea of Okhotsk	1845	Unknown[3]	1981	Unknown[2]
Western Arctic	1848	18,000	1988	7,800[4]

[1] Year corresponds to early commercial whaling; but may not correspond to first year of the fishery (in literature).
[2] Perhaps less than a few hundred.
[3] Variably estimated by Soviet scientists at 6,000 to 10,000 but analyses of whaling records have not been published.
[4] Ninety-five percent confidence interval is 5,700 to 10,600, accepted at the 1988 meeting of the International Whaling Commission.

IWC quota for aboriginal subsistence whaling, the Soviet Union is allowed to take approximately 179 grays per year.

The Chukot Eskimos don't hunt the whales themselves. They're taken by government-sponsored whaling cooperatives using a former commercial whaling vessel. The grays are landed near coastal Eskimo villages along the eastern shore of Chukotka; and the Eskimos haul them onto the beach to butcher them for local consumption. Although traditional subsistence whaling no longer exists in the eastern Soviet Union, whale festivals and other ceremonies connected with the hunt are still observed.

In the last two years, the Soviet delegation to the IWC has requested a take of two to four bowheads per year for the subsistence use of the Chukot Eskimos. But each time the Soviet delegation withdrew the request prior to any commission vote.

One recommendation, from a less than fully informed European delegate to the IWC, suggested that the Alaskan Eskimos be encouraged to go after gray whales instead of bowheads. Although they are allowed to take a small number of gray whales each year under the IWC aboriginal exemption, Willman Marquette, an expert in Arctic whaling, and I concluded that gray whales are not a suitable replacement. Between 1925 and 1982, Alaskan Eskimos landed 505 bowheads but only 47 gray whales; many of them were taken by a single whaler from the village of Gambell on St. Lawrence Island.

Most Eskimos we interviewed said they don't like the taste of gray whales, especially the muktuk. More important perhaps, they believe the gray is more dangerous to hunt than the bowhead (on St. Lawrence Island, the gray is known as the "devil" whale). Also, for the majority of whaling villages, grays aren't abundant or predictably available, so a hunt doesn't seem to be worthwhile for the Eskimos. When gray whales do appear in coastal waters of Alaska, traditional subsistence villagers prefer to go berry picking or catch fish in the local streams, or just enjoy the all-too-short summer warmth of the Arctic.

Developing a Systematic Census

Long-term studies of the Western Arctic bowhead whale started in 1973 when Marquette began monitoring the annual take of bowheads by Alaskan Eskimos at Point Hope and Barrow. He continued his work until 1982 when the Alaskan Eskimo Whaling Commission and the North Slope Borough became responsible for monitoring the hunt. I began studying the distribution, migration, and numbers of bowhead and beluga whales in 1976, supported in part by a small two-year contract with the Minerals Management Service, administered through NOAA's Outer Continental Shelf Environmental Assessment Program. This work was reorganized and greatly expanded in 1978 with funds from NOAA after the IWC voted to limit the take of bowheads by Alaskan Eskimos. The purpose of the research

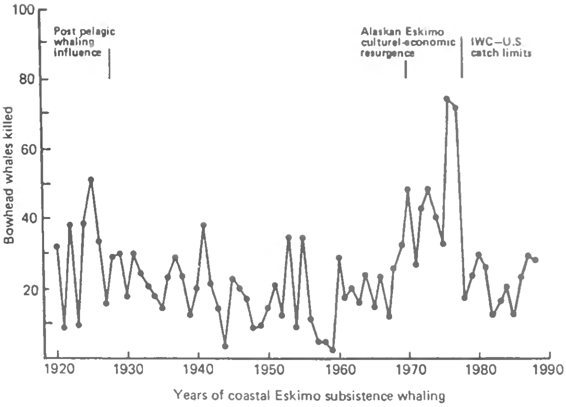


Figure 4. Annual number of bowheads killed by Alaskan, Canadian, and Soviet Eskimos this century after pelagic commercial whaling ended in 1919. No bowheads have been landed from shore-based operations by Canadians since 1922 or by Soviets since 1975.

was to determine how many bowhead whales are in Alaskan waters, and what effect the Eskimo hunt has on the recovery of the bowhead population.

Several unsubstantiated estimates made in the mid-1970s put the bowhead population at no more than several hundred to a thousand or so animals at best. With as many as 70 to 75 whales killed in 1976 and 1977, great concern was voiced whether this stock of bowheads could sustain such a catch. The available whaling records clearly showed, however, that the two years were unusual (Figure 4), even though the level of take had begun to rise a few years before.

Our job was to develop a systematic census and to determine the life history of the species. The biggest problem was knowing how many whales were actually being seen by the census crew. This raised many questions. Did a component of the population escape detection by taking a different migration route in the spring—say, into Soviet waters? How many whales were passing by the census sites before and after the census began each season? How many came by during periods of poor visibility, or when there was no one out on the ice to watch?*

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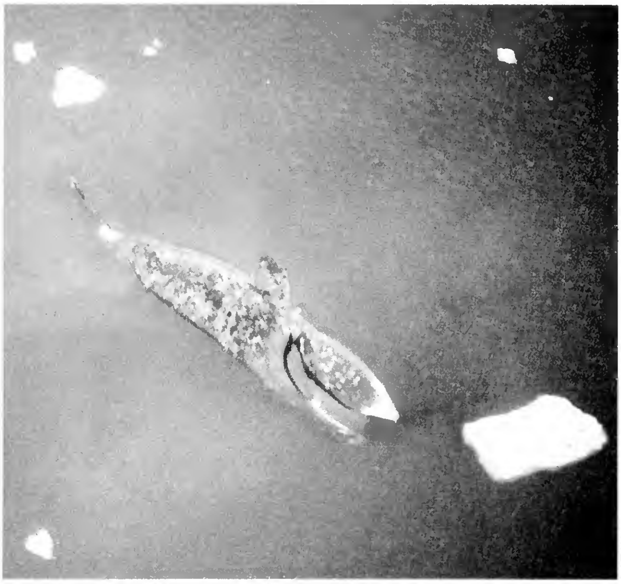
* Five census components have been identified for estimating total abundance of bowhead whales in the Western Arctic. The estimation procedures can be approximated by:

$$T = \sum_{i=1}^{5} C_i$$

where T = total population size; and C_i = i-th component of the population. The five components are: number of whales counted at the Point Barrow ice-based census site during the spring migration (C_1); number of whales passing the census site before the annual census begins (C_2); number of whales passing the census site after the census ends (C_3); number of whales present but not seen or counted by the census team (C_4); and number of whales that do not migrate past Point Barrow (C_5).



A dead floating bowhead whale, struck and lost by Eskimo whalers in 1987. Notice the striking resemblance to the earlier drawing by William Scoresby, circa 1820, on page 55. Could such an abandoned whale have been the source of Scoresby's drawing, perhaps observed by the famous whaling captain from the mast or wheelhouse of his ship? (Photo by David Withrow, National Marine Mammal Laboratory)

Over the years each of these questions has been answered to one degree or another. Extensive land, aerial, and vessel surveys have shown that essentially the entire migration passes Point Barrow each spring (mid-April to mid-June). Only a small component of the population passes this point before and after the census. And under a cooperative U.S.-Soviet research program we have confirmed that the spring migration does not include waters off the north coast of Chukotka. Also, from photographic studies of individual whales, in which their body lengths are measured, and from biological data from landed whales, a picture of the life history of the species has emerged.

We now believe that adult female bowheads give birth every three to six years and become sexually mature when they've reached body lengths greater than 13 meters. Their age at these lengths remains unknown, but it is probably in excess of five years. (Maturity probably occurs at about the same age for males.) Conception takes place in late winter and early spring, gestation lasts more than one year, and calving occurs primarily from April through June but may last until August. The annual rate of calf production, that is, the percentage of calves in the population in any single year, is between one and 13 percent (average estimates are about seven percent). Most important, the rate may vary greatly from one year to the next. And while we have no idea of the natural mortality rate, "fishing" mortality has been determined for each year since 1973 in the Alaskan Eskimo hunt.

The most difficult problem remaining, and it is being explored by the North Slope Borough, is determining the proportion of the population missed at the census sites. That figure is critical to achieving the best estimate of absolute abundance for any one year, since weather and ice conditions have prevented obtaining a statistically reliable estimate of the trend in population growth from a series of abundance estimates over many years. In only three of the 11 years of counting bowheads have the data been sufficiently complete to be used as an estimate of abundance.

The IWC now accepts the North Slope Borough's estimate of 7,800 whales (with a 95 percent statistical confidence that the number is between 5,700 and 10,600). These figures are a source of great relief because our initial estimate at the end of the 1978 season was only 2,264 whales. This information, along with the known take by the Eskimos, helps determine the effect of the hunt on the recovery of the bowhead population.

Changes in Eskimo Life

The subsistence catch of bowhead whales this century has been divided into three periods that correspond with distinct activities marking changes in hunting effort. From 1920 to 1969, the average kill, which is determined by adding the number of whales removed from the population by actual landings and the estimated number killed by harpooning but not landed ("struck and lost"), was approximately 20 per year. During this period, no significant trends in the take of whales occurred, nor did any dramatic changes in the population demography take place relative to subsistence whaling. (I use 1920 as a cutoff year because the last commercial pelagic kill of bowheads took place in 1919, although a combined subsistence and shore-based whaling operation continued at a few sites into the 1920s.)

In about 1970, however, two changes occurred that would forever affect the Eskimo community. First came a significant increase in the cash-flow economy, which meant that more individuals could afford to participate in the hunt. (No longer made by the Eskimos themselves, many of the tools of the hunt—harpoons, pokes, blocks and tackle—must be purchased.) Second, there was a resurgence of interest in the cultural heritage of the subsistence hunt for bowhead whales. The result was a dramatic

increase in the take of bowheads, from an average kill of 21 whales between 1965 and 1969, to about 40 per year from 1970 to 1975. The greatest increase, however, occurred in 1976 and 1977 when an estimated 74 and 72 whales were killed, nearly twice the annual kill in the 1920–1969 period.

The very next year, in 1978, the United States began severely restricting the take after a strike limit (quota) was passed by the IWC. The average number of bowheads killed annually between 1978 and 1988 has been approximately 22 (Table 2), essentially equal to the average kill prior to 1970.

Whalers and researchers must cut trails through ice ridges, sometimes up to 10 miles "out to sea" from Barrow. (Photo by David Withrow, National Marine Mammal Laboratory)

Analysis of the Catch

Since 1973, systematic data have been collected on 275 bowhead whales landed (the "catch") at each village, including those struck and lost, the lengths and sex of most animals landed, and other information about the hunt. Between 1973 and 1988, of the nine active whaling villages, Barrow took the most whales (48 percent of the total catch). It was followed by Point Hope (18 percent), Wainwright (10 percent), Kaktovik (eight percent), Gambell and Savoonga (six percent each), Wales (two percent), and Kivalina, Nuiqsut, and Shaktoolik (one percent each). The one whale landed at Shaktoolik (a nontraditional whaling village) is excluded from any analyses because it was an anomalous kill using high-powered rifles and small aluminum fishing boats, and took place in a year of heavy ice (1980) when the bowhead migration was stalled at the Bering Strait.

In analyzing the distribution of the yearly catches among the villages since 1973, some interesting results emerged. First, five villages have actually increased the number of whales landed since the strike limit took effect in 1978, while four others have decreased their take (Table 3). There was a significant decrease in the number of whales landed between 1978 and 1988 compared to the previous five years. This was, of course, the objective of the quota system. Also, a major redistribution of the take resulted, with some villages obtaining a greater share of the catch than they did before 1978. (The distribution of the take since 1978 has been made by consensus vote of the commissioners and whaling captains of the Alaska Eskimo Whaling Commission, sanctioned through a cooperative agreement with the U.S. government.) The most significant changes, as a result of the quota, have been the increase in the autumn catch at Kaktovik and the spring hunt at Wainwright, where the catches have doubled and tripled, respectively. The take at Barrow and Point Hope, however, has declined by more than half.

More recently, from 1978 to 1988, the take of bowhead whales is essentially equal to that prior to 1970. By comparing birthrates and other parameters of their life history with the annual

Table 2. Take of bowhead whales by Alaskan Eskimos since a quota system was established in 1978 by U.S. agreement with the International Whaling Commission.

Year	U.S.-IWC Quota	Number of whales: Struck[2]	Landed	Killed[3]
1978	20	18	12	16
1979	27	27	12	23
1980	26	34	16	29
1981	32	28	17	26
1982	19	19	8	13
1983	18	18	10	16
1984	25[1]	25	12	22
1985	18[1]	17	11	13
1986	32	28	20	23
1987	32	31	22	29
1988	35	28	15	≤ 28[4]
Total	284	273	155	238
Mean	25.8	24.8	14.1	21.6
Standard Deviation	6.4	5.9	4.3	6.2
n	11	11	11	11

[1] The 1984-85 2-year strike limit (quota) was 43, with no more than 37 strikes allowed in any one of those two years.
[2] A strike constitutes a whale being hit with a harpoon and/or bomb from a darting gun or shoulder gun.
[3] Number killed estimated from Eskimo reports on the fate of whales struck and lost, plus the number of whales landed.
[4] The fate of six whales struck and lost is unknown, so for now, I presume they died.

Table 3. Average annual number of bowhead whales landed by Alaskan Eskimos at each village before (1973-1977) and after (1978-1988) initiation of a strike limit.

Village	Average Annual Whales Landed 1973-1977	Average Annual Whales Landed 1978-1988	Percent Change
Wales	0	0.4	+100
Nuiqsut	0	0.3	+100
Kaktovik	0.8	1.5	+ 98
Gambell	0.8	1.3	+ 97
Wainwright	0.6	2.3	+ 96
Kivalina	0.2	0.2	− 10
Savoonga	1.2	1.0	− 17
Point Hope	5.0	2.1	− 58
Barrow	15.4	4.9	− 68
Annual Average	24.0	14.0	− 42
Total whales landed	120	154	

kill of bowheads in this century, my colleagues Jeff Breiwick and Lee Eberhardt, and I have determined that this level of hunting is not likely to cause the population to decline. In fact, data on the population size in 1984 suggested that the bowhead population has been increasing. This was also the subjective view of a few scientists I talked with back in 1976, although most of the Eskimo whalers that Marquette and I interviewed (independently) then didn't think there had been much change. A kill of 22 whales per year, the current figure, represents less than one-half of one percent of the lower end of the 1988 population size estimate of 5,700 bowheads (a more conservative use of the data than either the mean estimate of 7,800, or the upper end of 10,600).

So what is the answer to my opening question: is the hunt imperiling the whales? It would seem from our investigations that the current take of bowheads by Alaskan Eskimos isn't likely to have a significant impact on the recovery of this bowhead population. There remains the question of the actual net rate of increase of bowheads, however, and this may never be known without an accurate estimate of the natural mortality rate or a precise long-term estimate of the trend in population growth over many years. Both of these parameters will be extremely difficult to determine because of the high cost of research and the very difficult environmental conditions in the Arctic. □

Acknowledgments

For their help in preparing this article, I thank Bill Marquette, Dale Rice, Dave Rugh, Jeff Breiwick, Chuck Fowler, Dave Withrow, Tom Albert, Thomas Napageak, Leola Hietala, my three "anonymous" reviewers, and the publications and graphics units of the Northwest and Alaska Fisheries Center of the National Marine Fisheries Service.

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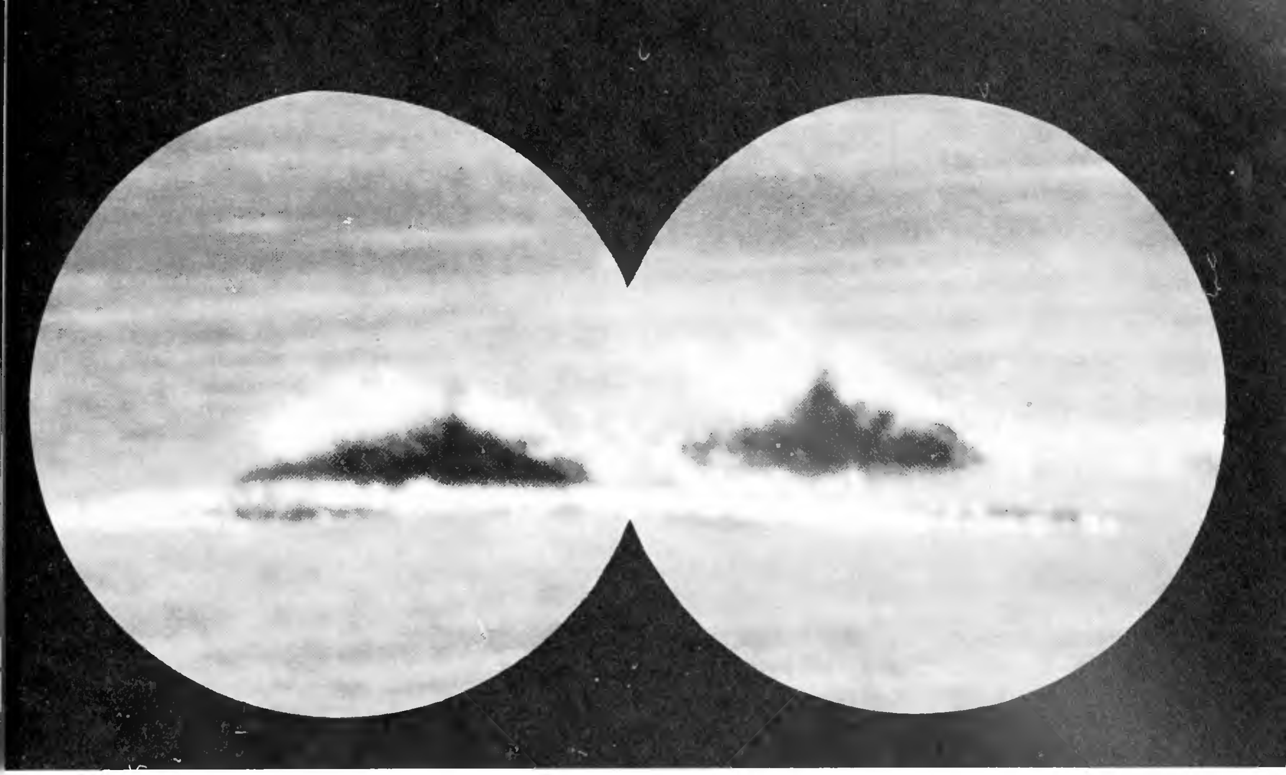

Two harbor porpoises as viewed from a survey vessel, showing what is (or is not) actually seen. (Courtesy of the author)

Harbor Porpoises and the Gillnet Fishery

Incidental Takes Spur Population Studies

by Tom Polacheck

The accidental death of tens of thousands of dolphins annually in the eastern tropical Pacific tuna purse-seine fishery is a well-publicized occurrence that continues to concern those interested in marine mammal conservation. But off the U.S. and Canadian coasts, a less well known marine mammal/commercial fishery collision is taking place. Each year unknown numbers of harbor porpoise, *Phocoena phocoena*, are entangled in gillnets. Although we can't say yet if these entanglements pose a threat to the long-term survival of the harbor porpoise, hundreds of the animals perish in this way each year.

Biologists of the National Marine Fisheries Service, an arm of the National Oceanic and Atmospheric Administration (NOAA), and other U.S. and Canadian scientists are working to improve methods of estimating the size of the harbor porpoise population that lives along their Atlantic coasts. Without dependable numbers, we cannot know how severely the fishery is affecting the porpoises, or form appropriate responses if the population is facing a threat. On two recently completed sighting cruises in the Bay of Fundy, we tested different field procedures for estimating how many harbor porpoises inhabit these waters. The tests have been important in validating the abundance estimation method underlying many of the assessments of marine mammal stocks.

As indicated by their name, harbor porpoises are generally found in coastal waters, but are also seen on offshore shallow banks

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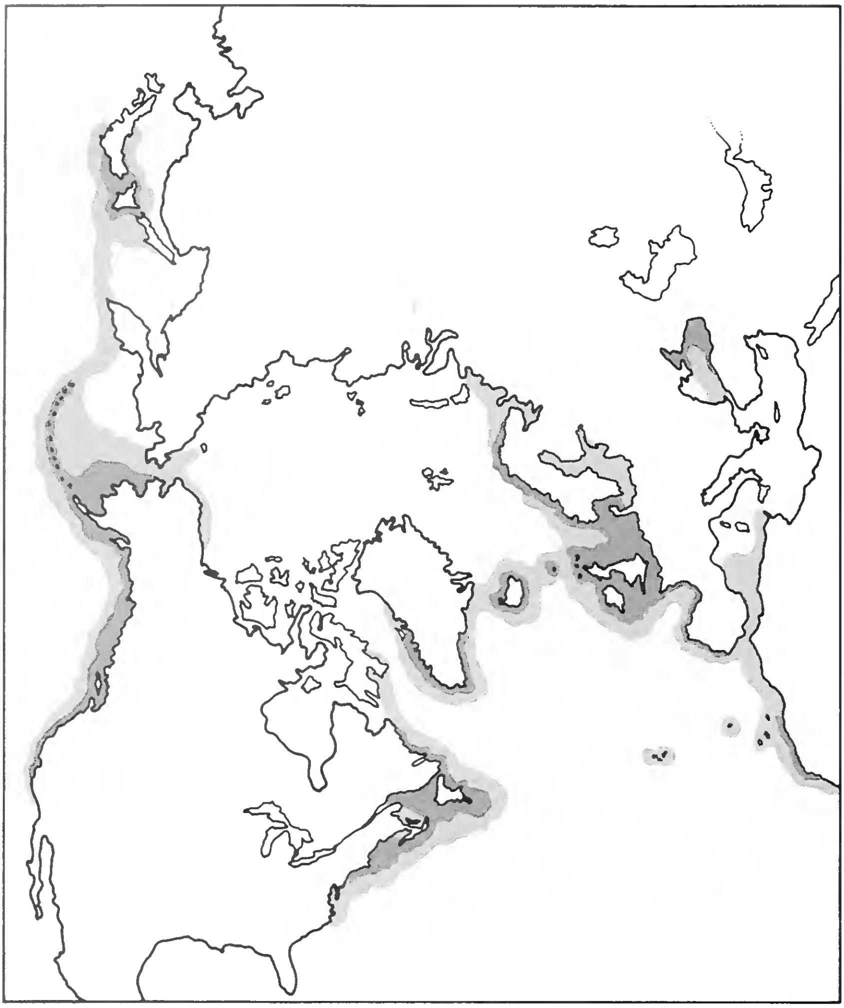
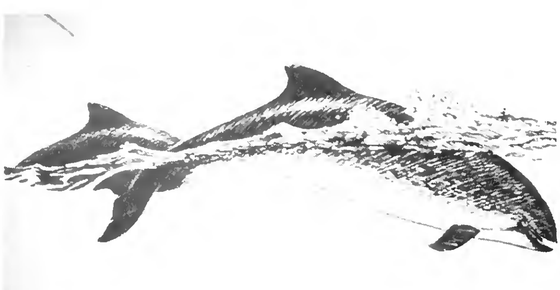


Worldwide distribution of harbor porpoise. Dark gray indicates areas of known consistent occurrence. Medium gray indicates occasional, peripheral, or probable range. (Data courtesy of David E. Gaskin)

(such as Georges Bank and the Grand Banks) and around isolated islands. They are a temperate species, confined to the northern hemisphere, and live along both the Atlantic and Pacific coasts, as well as along the shores of the Black Sea. As one of the smallest cetaceans, the harbor porpoise is also one of the most difficult to observe at sea. Maximum size is about five feet,



Harbor Porpoise. (Drawing by John R. Quinn)

and maximum age is about 13 years. They generally form schools of fewer than 10, show little of themselves when surfacing, and rarely, if ever, ride bow waves or jump—all of which further contributes to the difficulty in sighting them.

Harbor porpoises reach sexual maturity at age three or four, and females give birth to a single calf after a gestation period of about 11 months. Females can reproduce every year, but we're not sure whether a one- or a two-year calving cycle is more common. The age at sexual maturity, life span, and timing of the calving cycle combine to give a number known as the maximum annual net population growth rate. For the harbor porpoise this rate probably is low, suggesting that populations cannot sustain high rates of kill. They happen to be one of the more vulnerable marine mammals to incidental capture by commercial fishing gear, and are particularly prone to entanglement. Their nearshore habitat, small size, and diet of commercially harvested fish contribute to the magnitude of the incidental

and/or directed takes occurring throughout most of their range.

Harbor porpoises are distributed into a large number of relatively small and isolated populations. The exact geographic range of the various populations in the Atlantic is not known. The impact of incidental takes is therefore most important at small geographic scales relative to the species' overall distribution. Animals from the Bay of Fundy southward are generally considered as a single population with their typical southern limit probably being Cape May, New Jersey, although carcasses have washed up as far south as North Carolina.

During late summer and early fall, most of the population appears to congregate in the Bay of Fundy and the northern Gulf of Maine. Its distribution and movements during the rest of the year are more diffuse and not well documented, except for the northeasterly movement of animals along the coast in spring and early summer. We're not sure why they move around like this, but it is likely that they follow the migrations of their principal prey, and are spurred to move by seasonal changes in temperature and other environmental factors, possibly relating to breeding and calving.

Their distribution means that assessment and management are the joint responsibility of the United States and Canada, and that research is most easily carried out within the Bay of Fundy. Biologists at the University of Guelph headed by David E. Gaskin have taken advantage of this situation, and began studying the ecology and behavior of harbor porpoises there in 1969.

Question of Threat Not Resolved

During the 1800s, the Passamaquoddy Indians ran a small commercial fishery for harbor porpoise oil, considered especially good for watches. The meat was also consumed locally. No accurate records document the extent of this fishery, so we cannot place the current incidental kills in a broader historical perspective.

The kill rate—along with reproductive rates, natural mortality, and population size—is a yardstick for the magnitude of the problem, and indicates whether a population is likely to sustain itself. Kill rates are most easily calculated from estimates of population size and total numbers killed. Along with the Canadian studies, recent NOAA Fisheries-sponsored research on harbor porpoise in the Gulf of Maine and Bay of Fundy area has focused on estimating the abundance and number of animals killed.

Marine mammal takes in the United States are regulated by the Marine Mammal Protection Act (MMPA) of 1972 and subsequent amendments. Without a permit, all incidental kills are illegal under the MMPA, which forbids the taking of marine mammals from depleted populations. Determining whether a population is depleted under the terms of the act is not simple, however; it requires an estimate of the current population relative to the largest population sustainable by the ecosystem—usually considered to be the population before it was affected by any fishery. The most common method of determining population depletion under the MMPA requires a current population estimate and a complete series of historical kill estimates.

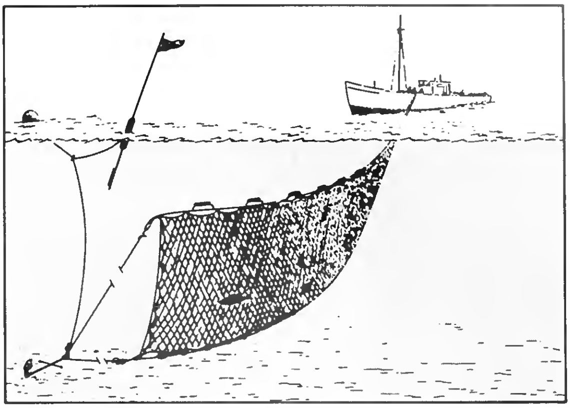


Figure 1: Bottom-tending gillnets are a string of up to 20 panels of five-and-a-half- to six-and-a-half-inch monofilament mesh net. Each panel is about 15 feet high by 300 feet long. Nets are anchored in 200 to 600 feet of water, with the bottom at the seafloor and the top buoyed, so the net hangs vertically in the water. Fishermen normally set three or four strings at a time, and leave them in place for one to three days. Fish swim headfirst into the net and get trapped when they are unable to continue forward because of the size of their bodies, and unable to back out because their gills catch on the mesh (hence the name). Harbor porpoises get entangled in the nets and drown.

Bottom-tending gillnet fisheries are responsible for the largest incidental take of harbor porpoises in the Gulf of Maine and Bay of Fundy (Figure 1). About 10 percent of the major groundfish (haddock, cod, pollock, etc.) landings in New England waters are taken by gillnetting, and this figure rises to about 20 percent if only the Gulf of Maine fisheries are considered. Gillnet effort can be measured either by counting the number of vessels engaged in gillnetting, or calculating the number of net-days* fished. By either method, gillnet effort varies annually and seasonally, with most of the effort by small (34- to 50-foot) vessels on day trips.

Vessels operate out of numerous and often small ports, especially along the Maine coast, making statistics difficult to collect. Even the number of vessels operating in the fishery is not known precisely, though there are at least 100 vessels, and the number is increasing. The Canadian gillnet fishery in the Bay of Fundy is smaller and better documented. Most of the gillnet effort occurs in the western portion of the bay, where 19 gillnetters were active in 1986, 28 active in 1987, and 21 in 1988. The Canadian

* Net-days are calculated by multiplying the number of 15-foot by 300-foot net panels set times the number of days these panels are left to soak.

fishery is seasonal, concentrated in the summer and early autumn months when the densities of harbor porpoise are highest there.

In the western Bay of Fundy, Andy J. Read and Gaskin have determined with reasonable precision, by direct observation and surveys, that the number of animals killed by Canadian gillnetters was about 105 animals in 1986, and 129 in 1987, or about 4.6 and 5.5 animals per fisherman each year. At most, only a few animals are believed to be taken by fishermen in other parts of the bay.

Comparable information on the incidental kill by U.S. gillnetters in the Gulf of Maine does not exist because of the diffuse nature of the fishery and the fact that comparable studies have not been done. The only reliable information comes from a NOAA Fisheries-sponsored study by James R. Gilbert and Kate M. Wynne of the University of Maine. These researchers applied for a general small take exemption permit under the MMPA from 1984 to 1986 that allowed them to distribute individual permits to fishermen. Without these permits, the fishermen would have in effect confessed to violations of the MMPA by reporting their incidental kills. Permit holders were to record their takes in logbooks that were to be returned anonymously at the end of the year.

Participation in the permit program was voluntary. But less than a quarter of New England gillnetters chose to take advantage of the legal protection afforded by a permit, probably because some felt that participation in the program was not in their own best interest. Gilbert and Wynne focused their study in ports where they thought incidental kills were most frequent, so the 11 to 22 fishermen who took part in the program each year probably represented a larger fraction of the gillnet effort affecting harbor porpoises than their numbers might indicate.

Only about 60 percent of the permit holders returned their logbooks. The number of harbor porpoises acknowledged to have been killed by reporting permit holders was 30 for 1984, and 107 for 1985, or 4.3 and 8.2 animals per fisherman, figures similar to those of their Canadian counterparts.

At-sea observation yielded a kill rate of 0.0037 animals per net-day. Direct comparison of the at-sea observation figure with those derived from the logbooks of reporting permit holders is not possible because the logbooks contained no effort information, but the two rates are not inconsistent if permit holders fished 30 to 75 days a year. However, extrapolation of these kill rates to the entire New England gillnet fisheries is not reasonable because of lack of detailed information on the gillnet effort, the localized and seasonal nature of the takes, and the nonrandomness of the sample of permit-holding gillnetters. Gilbert and Wynne suggest that the reported number of kills by permit holders is a lower limit for the actual number killed, and that an upper limit might be 600—based on the mean annual kill rate per fisherman and their estimate of a maximum of 120 gillnetters.

Besides the bottom-tending gillnet fisheries, there are three other known potential sources of incidental takes. The first is weirs* used to catch herrings. The second is surface gillnets used in the winter fishery for mackerel in Cape Cod Bay, and the third is subsistence hunting by Passamaquoddy Indians.** The magnitude of the kill from these three sources, while not well documented, is considerably less than from bottom-tending gillnets—perhaps on the order of 50 animals per year—based on observed kill rates in weirs and surface gill nets.

Adding up the observed sources of mortality would suggest an annual kill of at least 280 animals (130 by Canadian gillnetters, 100 by U.S. gillnetters, and 50 from other sources). This figure should be considered as a lower limit, since we suspect that substantially more animals are killed. An upper limit is harder to achieve, but it might be about 800 animals (600 by U.S. gillnetters, 130 by Canadian gillnetters, and 50 by other sources).

How serious a threat these kills are to the population depends on the size of the population. Scientists from the New England Aquarium, the University of Rhode Island, and the University of Guelph have surveyed parts of the range of the harbor porpoise population from airplanes and ships. These surveys have helped to clarify the scope of incidental take problems by estimating the population to comprise between 5,000 and 18,000 animals. However, none of the surveys to date were designed to either assess the

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Tail fluke of a harbor porpoise captured in a gillnet by a Canadian fisherman in the Bay of Fundy. White marks are from where the tail had been caught and entangled in the net. (Photo courtesy of the author)

* A weir is a kind of trap built in shallow waters. It uses nets, anchored at the bottom and reaching to the surface to guide fish into a collection device.

** While reports exist for small kills by native hunters until the early 1980s, cetacean researchers working in the Passamaquoddy Bay area have not noted any signs of porpoise hunting in recent years and believe that it may have stopped completely.

Line Transect Surveys Explained

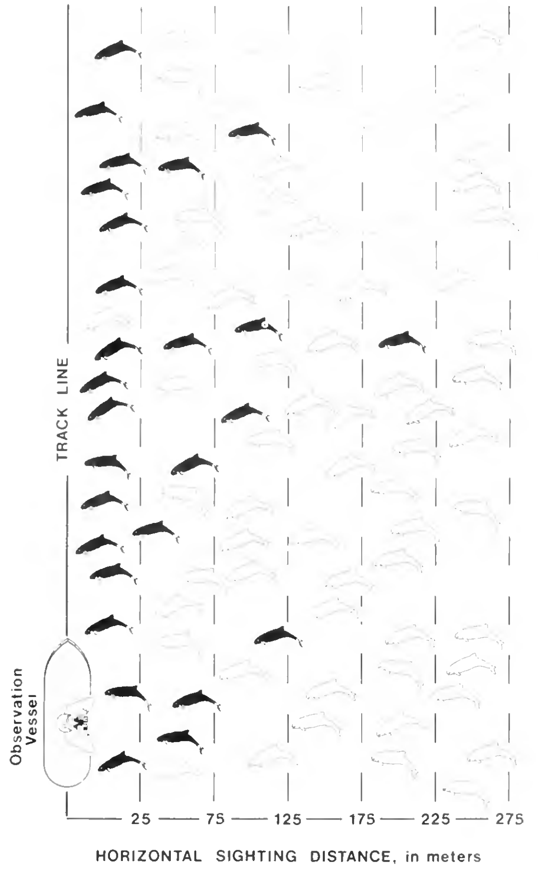
An understanding of the problem inherent in estimating abundance from a line transect survey can be achieved by comparing line transect surveys with the more easily understood method of strip transects. Strip transects are a common census technique for stationary, easily detected objects. A series of strips of a given width are randomly selected and all objects within the strip are counted. Density is calculated as the total number of objects sighted divided by the area surveyed, and total abundance is estimated as the product of the density times the total area of interest. A line transect survey is analogous to a strip transect except that not all objects within the strip are seen and the width of the strip is not known.

In the case of harbor porpoise populations, line transect theory attempts to account for undetected animals. This is accomplished by assuming that the probability of detecting animals on the surface decreases with increasing distance from the observer. Common sense, as well as most survey data, support this assumption. Furthermore, all animals directly on the track line are assumed to be sighted. With this assumption and the observed distribution of sighting distances, estimates can be made of the fraction of all animals at any distance from the vessel represented by those that were actually seen. The relationship between the probability of detecting an animal and its distance from an observer is referred to as the detection function.

At this point line transect theory is no longer simple. Various mathematical models, some of which are analytically and/or computationally difficult, have been used to estimate the detection function. Different models often yield substantially different results. Appropriate model selection based on the actual field situation and the observed data is critical to a valid abundance estimate. Once the probability of detection can be specified as a function of distance, calculation of density estimates is mathematically straightforward, and similar to a strip transect.

The application of line transect methods to marine mammals poses a number of practical and theoretical problems, including:

- *The actual distance to the animal must be known.*
- *Animals are continually moving on and off the track line.*
- *Animals beneath the surface cannot be seen (even if directly on the track line).*
- *The probability of detecting an animal at a given distance is not constant but will vary with observers and environmental conditions (sea state, glare, haze, and so on).*



Example of the number of sightings of harbor porpoises at different perpendicular distances from the vessel's track line. Black animals indicate porpoises sighted, white animals indicate unseen porpoises assumed by line transect theory to exist in the survey area. The data represented here were collected during four half-hour transects in the western Bay of Fundy from two different height platforms aboard the *R/V Gloria Michelle* (the crow's nest and the wheel house).

continued from page 66
magnitude of the overall problem, or provide management advice. These surveys were geographically limited, and had some detailed technical and methodological problems. In order to resolve some of these problems, the NOAA Fisheries Woods Hole Laboratory tested various survey procedures for harbor porpoises on two recent cruises.

An Exercise in Line Transect Theory

Estimating the size of marine mammal populations is not an easy task, but since this figure is so important for assessment purposes, the task has constituted a large fraction of all research on marine mammals. The International Whaling Commission, located in Cambridge, England, has been the forum for much of this research. For whales and dolphins the primary method for estimating the size of these populations is to do transect surveys, which consist of locating schools of animals from airplanes or boats, counting the numbers of schools located, charting their positions relative to the observers, and estimating the number of animals in an average school. The path to estimating total abundance from such data is guided by a body of statistical mathematics known as line transect theory, and the computations encountered along the way can be complex (see box).

NOAA Fisheries conducted its first cruise to develop and test line-transect survey procedures for this harbor porpoise population in the summer of 1987. While NOAA Fisheries and others have used line-transect methods previously for several species of dolphins and whales, including the harbor porpoise, each species and region requires unique field procedures to accommodate species-specific behaviors, constraints of the observation platform, and geographic and weather conditions. On this "survey design" cruise, we addressed practical considerations such as viewing height, optimal number of observers, binocular use, and sea states that allow for profitable viewing. The cruise took place in late August in the western Bay of Fundy, since the animals move into this area during late summer. NOAA's *R/V Gloria Michelle*—a 65-foot converted Gulf shrimp trawler—was the searching platform. While the cruise provided answers to many survey design questions, it also identified some potential problems that needed to be addressed before a full survey could be undertaken.

One significant finding was that the Bay of Fundy was shown to be an excellent site for testing and validating line transect methods for cetaceans. In most cetacean surveys, only a few schools are seen each day, and these are seldom concentrated in nearshore waters. This means that very extensive cruises in large research vessels are required just to obtain the minimum amount of data to calculate a detection function. We were overwhelmed with sightings; in fact, one transect had to be terminated because the data recorder couldn't write fast enough. The sighting rate during the cruise was about 5.2 schools per kilometer—much higher than the rates of 0.13 schools per kilometer in harbor porpoise surveys along the U.S. Pacific Coast, and 0.03 schools per kilometer in the Black Sea.

We learned some important lessons from this cruise. If we used binoculars for searching in areas of many schools, it almost became a nightmare to differentiate between the schools we had already counted and newly sighted ones. Searching by the unaided eye was much better because the available binoculars could then be used to identify species and count the animals in the various schools. And since the binoculars were used to obtain this more detailed information, the vessel was able to stay consistently on the track line. This contrasts with many shipboard marine mammal surveys, where the initial sightings are made at long distances, on the order of miles, often with binoculars, and the vessel has to break from the survey track to allow researchers to identify species and estimate group sizes. Besides the obvious increase in efficiency, the real advantage of not having to break from the track line was that two or more teams of observers could simultaneously search at different heights on the same vessel. This provided us with an ideal system for testing line transect survey methods.

Determining the difference in estimates made by teams at different heights was the prime objective of a follow-up cruise in 1988. Since both teams were searching the same water at the same time, the true density of porpoises was the same for both teams. The difference in the number of animals seen reflects the difference in the detection functions. By rotating observer teams between platforms and keeping detailed records of the location and time of each sighting, we examined in addition to searching height various factors related to the detection process such as boat speed and weather conditions.

Although the data from the 1988 cruise are still being analyzed, the cruise proved the potential of the multiple observer team approach for conducting experiments to validate and refine line transect methodology. (The only difficulty encountered in the experimental design was getting three observers and one recorder to fit in one small crow's nest.) In just three days of searching, 923 sighting were made—489 by one team and 434 by the other. The sightings exceeded the number obtained during previous cetacean surveys, and so will give insight into the adequacy of line transect methods for cetaceans.

Developing the tools for evaluating the magnitude of the incidental kill problem has been the aim of research performed to date. As estimation methods are refined, the issue of whether a real threat is posed by incidental kills to this population of harbor porpoise will become clear. Certainly the implications of a take of 280 animals from a population of 18,000 are very different than of a take of 800 animals from a population of 5,000. The former may be sustainable, the latter most likely cannot be.

Additional information collected by

Observers searching for harbor porpoises aboard the R/V Gloria Michelle. *(Photo by the author)*

Canadian scientists at the University of Guelph suggests that there has been a shift in the population towards younger and smaller animals in the 1980s, and that juvenile harbor porpoises are growing faster than they did in the 1960s. These are demographic responses biologists associate with declining populations. While these findings cannot be considered conclusive because of limited sample sizes and sampling procedures, they lend urgency to the need for an adequate assessment.

The prospect for obtaining reliable information on the U.S. incidental kills has greatly increased by the passage of an amendment to the MMPA in November, 1988. Under this amendment, incidental takes of most species will not be illegal during an interim five-year period. This provision was designed to facilitate research for assessment purposes, and fishermen will be required to report all incidental takes to NOAA Fisheries. The amendment also provides for observers to be present in those fisheries where incidental takes are frequent. In addition, NOAA Fisheries will conduct a two-week survey cruise this summer to determine the southern and off-shore boundary of the New England

harbor porpoise population. Eventually a survey of the total population will be undertaken.

Who Threatens Whom?

One avenue of porpoise protection is gear modifications that might reduce or eliminate the incidental take, such as making the nets more "visible" to the porpoise sonar system. Similar research in other fisheries with other small cetaceans has not been successful in the past, but one always remains hopeful. There is also a need to better understand when and how the porpoises become entangled. If more porpoises are trapped when the net is being set than when the net is in place on the bottom, then developing faster-sinking nets or setting nets only when the porpoises are out of the area will help the situation. Animals apparently do not get entangled when the net is being retrieved since live or recently killed animals are never observed.

If it is true that harbor porpoises are attracted to the gillnets as a source of food, then eliminating or reducing the incidental kills would most likely require seasonally prohibiting gillnetting on many of the fishery's best grounds. Such an action could threaten the viability of the fishery.

The problem of the incidental take of harbor porpoise exemplifies some of the problems that face both the marine scientist and society with regard to the interaction of marine mammals and commercial fisheries. Both are highly valued and represent issues of concern to various segments of society. The total number of animals killed may not appear large to some, and fishermen may find it hard to believe that their incidental takes are of any significance. However, the populations of small marine mammals tend to be highly vulnerable to low levels of exploitation (article, pp. 5–11). On the other hand, commercial fisheries represent peoples' livelihoods and way of life. Fisheries, particularly those operating at small scales, often cannot sustain large additional costs and remain competitive.

As critical as the need for more information may be, resources for research are scarce and many important projects compete for limited funds. Population biology studies of marine mammals are expensive compared to those of land mammals, and the information required for assessment calls for long-term studies. Moreover, even the best possible assessments are likely to be imprecise, leaving large uncertainties. Yet, these difficulties should not be used as an excuse to do nothing. On conservation issues, ignorance has too often resulted in inaction. Competing concerns need to be balanced, and reasonable solutions found. □

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The author (left front) and co-workers returning home after a successful day of porpoise surveying. (Photo by Anne Richards)

Dolphins in Different Worlds

A group of Hawaiian spinner dolphins resting in shallow water near shore. (All photos in this article by Bernd Würsig)

by Bernd Würsig, Melany Würsig, and Frank Cipriano

Much has been written in the last 20 years about the supposed beguiling nature and intelligence of dolphins. The American public generally thinks of these sleek oceanic mammals as human-like, yet without human faults, leading lives of ease and thoughtful kindness. In reality, they must work hard to make a living in a harsh environment; their food supplies are unpredictable, and predators—such as large sharks and their own relatives, the killer whales—may strike at any time. As do all animals, dolphins must contend with diseases and are known to have especially high parasite loads—flukes, tapeworms, and roundworms—that can cause discomfort and death. Mass strandings of entire schools of dolphins, pilot whales, and sperm whales may be partly due to debilitation by parasites (box, page 79).

So, dolphins do not have a carefree existence. They must be efficient hunters, skilled at detecting and avoiding potential predators, and they need a social system that allows for the most energy-efficient raising of their young—their genetic ticket to the future. Because of the environmental constraints on their lives, we might expect dolphins in different habitats to structure their behavioral patterns and group organization differently. We find this is indeed the case for the dusky dolphin, *Lagenorhynchus obscurus*, which we have studied in detail in two radically different environments in the southern hemisphere.

Dusky dolphins, at a length of about 1.8 meters, are one of the smaller dolphins. They occur off the coasts of South America, South Africa, New Zealand, and possibly the Kerguélen Islands of the southern Indian Ocean. They are closely related to the several other species of the

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same genus found in all the great temperate seas except the Indian Ocean, but none of these other species has yet been studied in detail.

We have observed dusky dolphins off the coast of Patagonia, Argentina, since 1972. These animals live in shallow waters, close to shore. They feed mainly at the surface on schools of southern anchovy, *Engraulis anchoita*. Their search for and herding of foodfish are highly synchronized, as is their feeding. Such cooperation makes for high feeding efficiency.

In 1984, we initiated a comparative study off the South Island of New Zealand. In contrast with the shallow-water environment of Argentina, the shoreline of volcanic New Zealand drops abruptly into the ocean. Off Kaikoura, where we have concentrated our study, the Kaikoura Submarine Canyon brings depths of 2,000 meters to within two kilometers of shore. This depth allows a layer of phytoplankton, zooplankton, and fish to rise at night and sink during the day. The vertical movements of this deep-scattering layer (DSL, footnote, page 17) are related to the amount of sunlight reaching through the water; in the productive and slightly murky waters east of New Zealand, the DSL travels down to 200 or 300 meters in the day and comes almost to the surface at night.

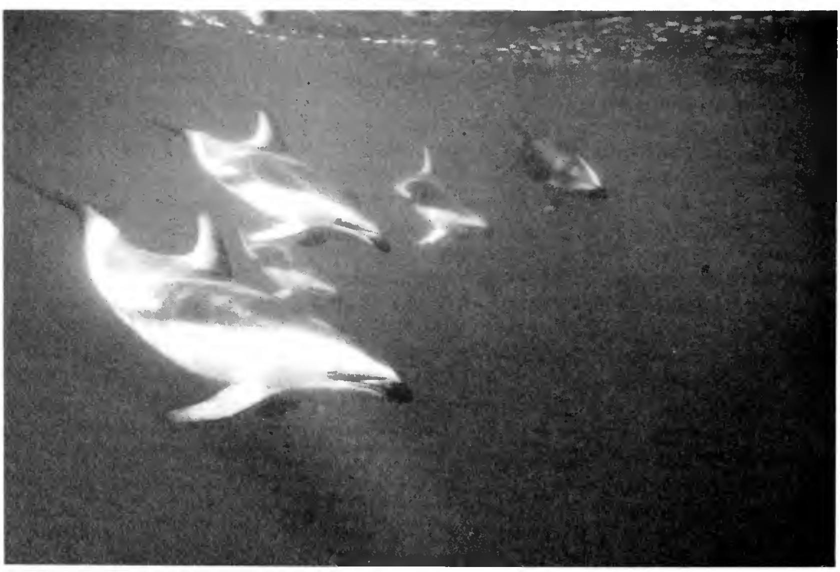
In the New Zealand waters, dusky dolphins depend very little on schooling fish near the surface. Instead, they feed mainly on fish and squid associated with the DSL. Because their feeding mode is different from that found in dolphins off Argentina, many aspects of group structure and movement patterns differ as well.

Argentine Duskies

In shallow waters of Golfo San José, Argentina, dusky dolphins generally forage in small groups of eight to ten, usually within five kilometers of shore, in water less than 200 meters deep. At times up to 30 small groups can be observed, spaced from one to eight kilometers apart, in search of schooling prey. These groups stay in contact with each other acoustically while diving, and visually while at the surface. We observed groups that had found prey making underwater sounds different from those made by dolphins that are still searching, and dolphins beginning to herd fish leap more than at other times. Large groups are more efficient at herding schools of anchovy than small ones, and it appears that methods for calling in distant groups evolved because the food benefit for each dolphin is increased when groups join forces.

To herd fish into a tight ball, some dolphins harass the fish from below while others circle around the perimeter of the school. They drive the school—originally found at 10 or 20 meters below the surface—upward, and use the surface as a wall through which the fish cannot escape. Such cooperative herding appears essential to Argentine dusky dolphins in their effort to feed on small schooling fish. They keep the school tightly balled, so that when individual dolphins move through, they can take three to six fish at a gulp, and take turns at feeding and herding. When the fish are not held in such a tight unit, the fish split into many school fragments, dive, and escape.

An especially intriguing aspect of this cooperative herding is that a form of "temporary restraint" is taking place. That is, at any one time, rather than feeding, most of the dolphins are keeping the fish from escaping, while a few others take turns rushing through the contained school of fish to grab their mouthfuls. As yet, we do not know whether one animal's turn is mediated by some form of dominance hierarchy, or whether other, perhaps more egalitarian, decisions are made. Certainly the high degree of coordination relies on constant visual and



Off Patagonia, Argentina, dusky dolphins forage in small groups. When they locate schools of southern anchovy they aggregate into large schools and cooperate in herding and eating the fish.

acoustic communication, and we are only now beginning to understand some of these signals.

An orginal group of eight to 10 dolphins often increases to more than 200 by the time feeding is completed. After they have fed, high levels of social and sexual activity take place in the large group. We believe that much of this activity is similar to greeting ceremonies seen in terrestrial animals such as wild dogs, wolves, and chimpanzees. Animals that cooperate need to know each other well; social and sexual activity provides a large amount of information about other group members, helping to establish and maintain relationships. This has been observed in many animal societies, and is especially sophisticated in human society.

Like most schooling fish, southern anchovy tend to forego tight schooling at night, occurring in cohesive groups only during the day. Thus, Argentine dusky dolphins do most of their foraging in daylight. Small groups tend to meander in the early morning hours, usually finding food by noon, and aggregating into large groups to feed in the afternoon. They break into smaller bands again in the evening or at night, and rest at the surface with very little movement. When food is absent in a particular area, they can rapidly move more than 50 kilometers a day to explore a different area.

This daily behavior pattern occurs most clearly during spring, and less so in summer and fall when the anchovy aren't as plentiful inshore. In winter, anchovy are even more scarce, and dolphins hardly ever aggregate into groups larger than about 20 individuals, tending to stay within three kilometers of shore. They move slowly, as they alternate rest with apparent feeding on non-schooling prey in shallow water. There is enough food available for the dolphins to survive winter even in a rather restricted area. However, it is possible that the generally low level of activity and the lack of boisterous, large-group socializing is a strategy for conserving energy in a food-limited environment.

The spectacular leaping of dusky dolphins seems to occur more often during fish herding.

New Zealand Relatives

In New Zealand, the feeding and social behaviors of dusky dolphins are very different. Instead of traveling, as their Argentine kin do, in a widespread school with small groups spaced some distance apart, New Zealand duskies move in closely knit schools, made up of subgroups of about ten individuals. We usually see an unbroken and tight perimeter surrounding an entire school so that two- or three-hundred animals cover an area generally no larger than one square kilometer. The entire school travels in search of food as a directed unit rather than meandering in groups. We believe this is because these dolphins are using foraging methods other than the type used to locate sporadically occurring fish schools in Argentina.

Radio-tracking studies show that the school moves along depth contours. Gut content analyses reveal that dolphins feed on fish and squid generally found at depths of 100 meters or more. We imagine that they move through areas that constantly have good food supplies, much as fishermen move en masse to preferred fishing grounds.

Individual groups within larger schools of New Zealand dusky dolphins dive synchronously, probably to the DSL, and at times the entire school may disappear from the surface. We believe they dive synchronously to share information efficiently on the greatest concentrations of prey in the diffuse and patchy DSL, and possibly to stay in acoustic contact because of the ever-present danger of attack by deep-water sharks.

Cooperation may take the form of sharing information, but we suspect that herding as such does not take place. Most available prey items don't occur in tight schools and there is little time during a three- to five-minute deep dive for cooperative herding anyway. Additionally, groups within the school tend to surface together, generally remaining as discrete units within the school. This observation further indicates that between-

group interactions are not on a close physical level during deep dives, but are probably mediated acoustically.

New Zealand dusky dolphins are usually loosely aggregated in the entire school, so there isn't the same daily coalescing and dispersion of large and small groups that we see in Argentina. There is little variation in social behaviors, in contrast to the noticeable increase in these behaviors in postfeeding aggregations in Argentina. A lower, more continuous level of social and sexual activity probably occurs between members of dusky dolphin schools in New Zealand. It may be that less "greeting ceremony" behavior is needed because less cooperative feeding occurs. Here we are delving into uncharted grounds, however. For a true understanding of these behaviors, we need much more information on the relationship between cooperation and social activity.

Following the DSL

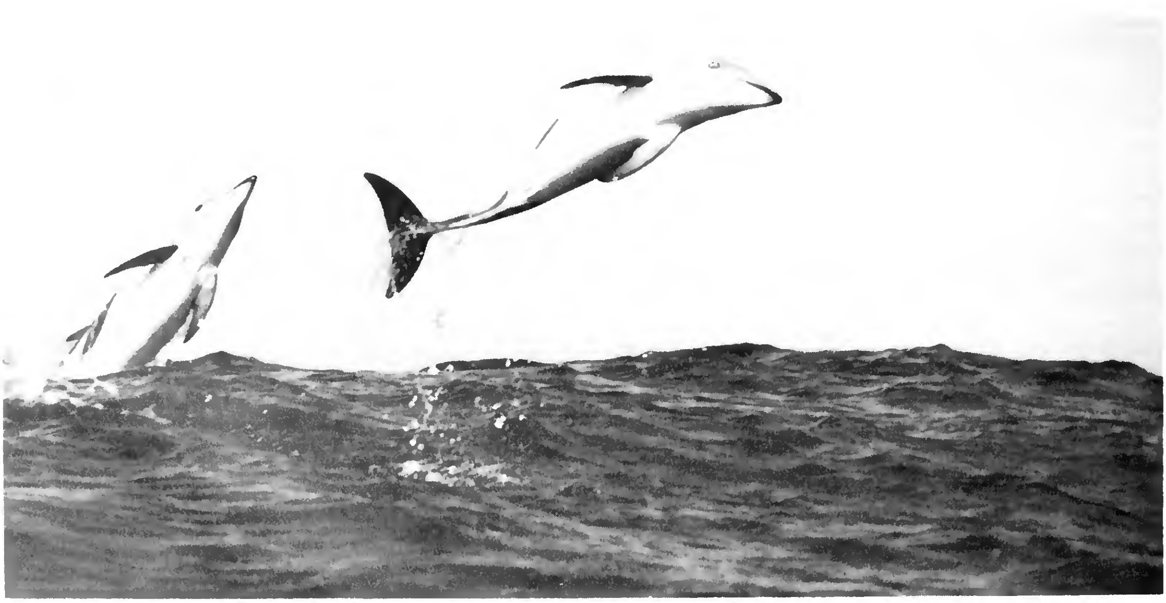
Because the DSL tends to migrate vertically on a daily schedule, we might expect to see shifts in behavior of dolphins feeding on organisms closer to the surface at night. In fact, New Zealand dusky dolphins do seem to follow this pattern. During summer and fall mornings, they tend to be close to land, often within a few hundred meters of shore. In late afternoon, they gradually move into deeper water, presumably to meet the rising DSL in pelagic waters during the night. During winter, dolphins are usually found farther from shore both day and night. We're presently investigating the seasonal differences in abundance of DSL-associated organisms that are most likely responsible for this seasonal change in dolphin distribution.

From this comparison of New Zealand and Argentine dusky dolphins, we see that there are strong differences in daily and seasonal patterns of movement and school structure, primarily due to differences in prey type and availability. But there are similarities as well.

In both areas, dolphins move close to shore when they are not feeding, probably to avoid predators such as deep-water sharks in New Zealand and killer whales in Argentina. Although small groups are dispersed rather differently within their schools, the size, cohesiveness, and composition of the groups appear similar. There are some composed entirely (or almost entirely) of females and calves; others only of juveniles; and still others include adult females, males, and a few subadults.

Some evidence suggests that the social organization of Argentine dusky dolphins is related to a "polygynous-promiscuous" mating system, in which males tend to mate with more different individuals than do females. We suspect a similar structure in New Zealand, but as yet have collected less information on social organization there. This mainly polygynous system is seen in other species of small dolphins and is probably inherent to general lifestyle, and less dependent on specific foraging and movement patterns. Nevertheless, as our studies continue, we wouldn't be at all surprised to see subtle differences in social structure related to the different ways the two communities make their living.

One difference already stands out. While groups are composed of varying proportions of ages and sexes in both communities, in Argentina, groups travel quite far apart, aggregating only to feed and socialize. In New Zealand, groups are usually found fairly close together



After feeding in the deep off New Zealand, these dusky dolphins engage in high levels of social activity.

Off Kaikoura, New Zealand, dusky dolphins travel in close schools, made up of subunits of about ten individuals.

within more confined school boundaries, and we expect that communication and social interactions can occur between groups at any time. We further suspect a physical structuring of New Zealand groups within the overall school perimeter, so that females with young are kept within the center, while adult-only groups may be found more often on the periphery. Although this has not yet been well documented in New Zealand, such structuring has been observed in the tropical Pacific spinner and spotted dolphins, *Stenella longirostris* and *S. attenuata,* that also travel within large perimeters.

A More Distant Relative

Along with Kenneth S. Norris of the University of California at Santa Cruz (UCSC) and Randall S. Wells of the Woods Hole Oceanographic Institution and UCSC, we have also been studying a different species off the western coast of the island of Hawaii, the Hawaiian spinner dolphin (also *S. longirostris*, but a different geographical race than the eastern tropical Pacific spinner).

Like New Zealand, Hawaii is a volcanic island, and depth increases rapidly within one to two kilometers of shore. Hawaiian spinner dolphins feed on DSL organisms, and have daily movement patterns akin to those of New Zealand dusky dolphins. However, in the clear, unproductive waters of Hawaii, the DSL sinks very deep during the day, apparently out of reach of the dolphins, since they do not feed during daytime. Like the duskies of Argentina, they split into small groups to rest near shore during the day. While this fission of large schools allows efficient foraging in Argentina, schools of Hawaiian spinner dolphins probably split up because only subgroups fit comfortably into the small nearshore bays accessible to them.

Since the behavior of Hawaiian spinner dolphins is somewhat between that of the more closely related Argentine and New Zealand duskies, we believe that habitat and food availability are much more important than phylogenetic differences in structuring group and school life of nearshore dolphins. □

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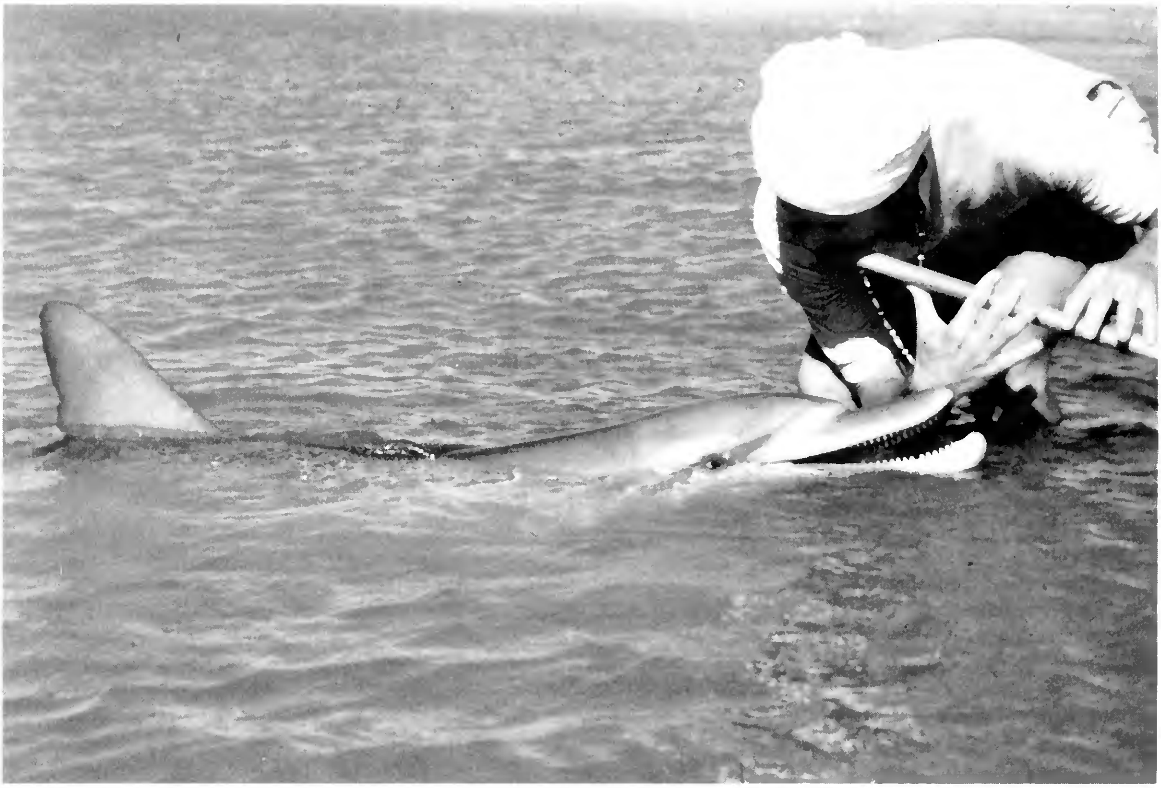
Unraveling the Dolphin Soap Opera



A bottlenose dolphin in Shark Bay, Australia showing a lively interest in music. (Photo by Claire Leimbach)

by William Booth

On the shores of Shark Bay in Western Australia, there is a beach where wild bottlenose dolphins, *Tursiops truncatus*, swim into knee-deep water and allow tourists to stroke their flanks and feed them frozen fish. Often, the dolphins return the favor by tossing the onlookers a fresh herring or nice piece of seaweed.

Fascinated by tales of Shark Bay and intrigued by the research potential of such a place, two undergraduate students traveled to Western Australia in the summer of 1982 to have a look for themselves. What Richard Connor and Rachel Smolker found was a mixed group of eight bottlenose dolphins so habituated to humans that they daily swam onto a beach "so shallow that they could be seen using their pectoral fins as braces against the bottom while lifting their heads of the water."

With only $1,000 in funding from the New York Explorers Club and no boat their first summer, Connor and Smolker simply watched the dolphins from the shore, yet they made a number of unique observations, including evidence of begging behavior among dolphins similar to that of wild chimpanzees. "It was like watching a soap opera," says Connor, who along with Smolker, is now a graduate student at the

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William Booth is a reporter for Science magazine, with whose kind permission this article is reprinted. It appeared in the 3 June 1988 issue.

University of Michigan in Ann Arbor.

In addition to amusing the tourists in a remote part of Australia, the habituated dolphins often brought other, more shy and retiring, dolphins with them. As Connor and Smolker began identifying individuals, it became clear that the eight friendly dolphins were part of a larger community of more than 200 animals residing in the shallow, clear waters of Shark Bay.

This remarkable site is now being compared to the Gombe Stream Reserve, a flattering allusion to the chimpanzee habitat on the shores of Lake Tanganyika so richly worked by Jane Goodall, who originally encouraged the habituation of wild chimpanzees by feeding them bananas. Says Irven DeVore, an anthropologist and primatologist from Harvard University who has visited Shark Bay: "These youngsters are sitting on the motherlode."

The comparison between Gombe Stream and Shark Bay does not end with the habituation of the residents. The dolphins are attracting some of the very same scientists whose previous work focused on the chimpanzees of Gombe and who now hope to compare the social lives of these two big-brained mammals, animals that live in such different media and are separated by at least 60 million years of evolution yet seem to share many social adaptations.

Comparisons with Chimpanzees

The first reports from Shark Bay, which are built upon nearly two decades of research on a community of dolphins in Florida, are revealing "a striking and remarkable convergence between the social systems of dolphins and chimpanzees," says Barbara Smuts of the University of Michigan, who studied chimpanzees with Goodall in Tanzania and is now launching projects at Shark Bay with Richard Wrangham, another primatologist who cut his teeth at Gombe. The two will oversee the work of Connor and Smolker and a third graduate student.

In the past, says Smuts, researchers have been frustrated in their attempts to make comparisons between terrestrial and aquatic mammals because of their inability to observe wild dolphins with the same intimacy and intensity that they could achieve with wild chimpanzees at sites such as Gombe. Such richly textured observations of individual and group behavior are crucial if comparisons between higher primates and dolphins are to be made. Captive populations of dolphins, with their small numbers of mixed animals in cramped aquariums, have been of limited value in unraveling social structures, says Smuts.

Until now, the study of dolphin social organization in the wild has been pioneered by Randy Wells of Woods Hole Oceanographic Institution and the Long Marine Laboratory at the University of California at Santa Cruz. Since 1970, when he began his dolphin days while still in high school, Wells has gathered an enormous amount of data on a dolphin community living in the warm, grassy shallows around Sarasota, Florida. In particular, by tagging, radio-tracking, and taking blood samples, Wells has pieced together much of what is known about the range and demographics of a stable community of dolphins.

"Randy has given us incredible information about who associates with whom, but not as much on who does *what* with whom," says Smuts. For unfortunately, the inshore waters of Sarasota are a murky green soup, making detailed observations of interactions difficult. In contrast, the water at Shark Bay is relatively clear and the animals allow boats to pursue them at distances of only a few meters. The dolphins at Shark Bay are so cooperative that they often roll over while riding the research boat's bow wave, giving observers a chance to sex the animals with a quick glance at the animal's genital slits. (Unlike Wells and his colleagues, who capture and quickly release animals, the researchers at Shark Bay will not handle the dolphins.)

The dolphins of Shark Bay interact freely with people, much to the delight of this youngster. (Photo by Claire Leimbach)

What makes dolphins so appealing to primate researchers is the fact that both dolphins and chimpanzees evolved to possess such big brains while adapting to very different environments. Says Smuts: "Once you start comparing chimpanzees and dolphins—and large brains and social systems separated by millions of years of evolution—you can ask some pretty interesting questions." The forebears of both animals were terrestrial mammals. About 60 million years ago, the ancestors of modern cetaceans were primitive ungulates with small bodies and small brains that returned to the sea, from which the extant suborders of cetaceans eventually evolved, one being toothed whales and dolphins. As Smuts notes, it is the dolphins alone among the cetaceans that exhibit such a dramatic increase in brain size. When compared to body size, the brain of *Tursiops truncatus* is below that of humans but roughly double the size value of higher primates. Like humans, both dolphins and

chimpanzees possess brains with an expanded neocortex and with extensive convolution, and much development is completed after birth.

Based on the work of Wells and as yet unpublished observations made at Shark Bay, a picture of the social lives of wild dolphins is beginning to emerge. Though the primatologists believe the social system employed by dolphins might prove remarkably similar to chimpanzees, Wells himself is not completely convinced. "I think anyone who tries to pin the dolphins on any one terrestrial animal will probably be disappointed," says Wells. Yet Smuts maintains that, combined, the social systems of dolphins and chimps are not shared by other mammals.

Like chimpanzees, for example, dolphin communities occupy a common home range, says Smuts. In Florida, Wells has established that his Sarasota community of 100 individuals lives along a 40-kilometer stretch of shallow bays and inlets that hug the barrier islands separating the Gulf of Mexico from the mainland, with the total range amounting to about 100 square kilometers.

A Fusion-Fission Society

Within their home range, both dolphins and chimpanzees live in an extremely fluid and flexible community, referred to as a "fusion-fission society," where individuals may join temporary parties of varying sizes, instead of operating in one relatively closed or rigid group. The females in both chimpanzee and dolphin communities have a tendency to travel in more limited, "core areas" within the home range, while the males roam to the periphery. The wandering males probably occasionally succeed in mating with a female from another community, thus keeping the populations from being reproductively isolated, says Wells.

Within the community, dolphins have a tendency to associate with members of the same sex and age, except in the case of females and young calves. Mothers and offspring form some of the tightest bonds in the community, remaining together until the calf is weaned between the ages of three and four years.

Indeed, like chimpanzees, sons and daughters may often closely associate with their mothers years after weaning. Wells reports that he has watched older offspring return to their mother's side for the birth of a sibling. "They seem to want to check out the new arrival," says Wells.

Female dolphins with calves are extremely cooperative. The mothers will often form "playpens" around youngsters and allow them to interact within the protective enclave. Episodes of "baby-sitting" are also common, where one female will watch another's calf while the mother is occupied elsewhere. In many cases, Wells says that the cooperating females are related.

As females tend to associate together, so do males. Perhaps the most intriguing of all male groups is the existence of persistent pairs or trios. Wells has seen many such pairings of both juvenile and adult males. In one case, two large, older, and heavily scarred males have been observed in each other's constant company since 1975. Connor is also seeing what he calls "coalitions" of two and three males in Shark Bay and is preparing several papers on the subject. "I can say the coalitions of males that I am seeing are extremely exciting," says Connor.

The rationale behind such behavior is only just emerging. Wells believes that the male pairs may protect each other from predation and cooperate in hunting. According to Wells, the teams are also capable of working in tandem to separate individual females from groups. In one anecdote published in 1987 by Wells, he describes two males flanking a female and chasing her.

At Shark Bay, Connor has repeatedly witnessed a behavior he considers "sexual herding," in which two or three males in a coalition will cooperate to intimidate a female and keep her close by their sides. Connor suspects the males intend to mate with their captive. In Sarasota, this hypothesis is supported somewhat by the presence of closely bonded male pairs even during the mating season.

Using DNA fingerprinting techniques and chromosome band analysis, Wells and Debbie Duffield of Portland State University in Oregon are currently examining blood samples taken from many of his male pairs in Sarasota to find out whether or not the males are related. The reason for the blood analysis is that it would be almost impossible to otherwise discern in the wild which male is fruitfully mating with which female because sexual encounters among dolphins are so common, says Wells.

The mating system for dolphins, like chimpanzees, is a promiscuous one. Males and females do not form long-term bonds. Females may mate with a number of different males. Among the males in Shark Bay, Connor observes constant sexual interaction, both heterosexual and homosexual. "There'll be a group of four or five males and it seems like one of them goes, 'Let's go get Pointer!' And the other males start mounting him with erections." says Connor. "So much of the sexual interaction appears to be purely social. The males are constantly mounting each other and mounting females not in estrus."

Indeed, Wells reports that male bottlenose dolphins have unusually large testes and that the sperm concentrations in their ejaculate is 300 times the mean concentration for humans, and 100 times the concentration for chimpanzees. Two-day old dolphins have exhibited erections, and dolphins in both captivity and the wild masturbate. In Sarasota, males have been reported to mount sailboats. Says Wells: "The early development of sexual behavior, many years before sexual maturity, suggests that sex is quite important in the lives of these animals." It appears that large brains may have something to do with the amount of sexual behavior that is pursued outside of any reproductive context, says Smuts. □

An Explanation for the Dolphin Die-Off

From July 1987 to March 1988, more than 740 bottlenose dolphins, Tursiops truncatus, *washed up dead on beaches from New Jersey to Florida, and possibly thousands more died at sea. Most of these animals had horrible lesions and peeling skin. Although it is not unusual to find a handful of dead dolphins each year, never before had there been such widespread mortality.*

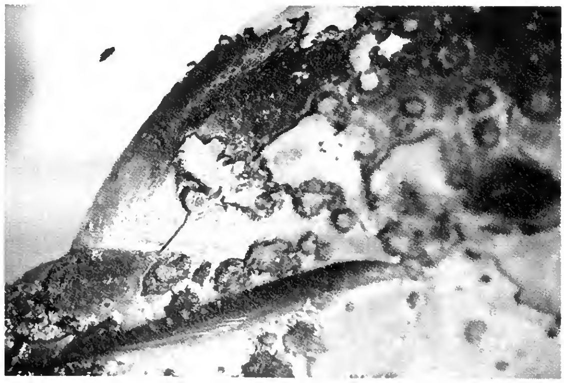
The immediate question that arose was whether the deaths were from manmade or natural causes. In August 1987, the National Oceanic and Atmospheric Administration (NOAA) established the Emergency Response Team, headed by Joseph Geraci, a professor of veterinary medicine in the pathology department at the University of Guelph, Ontario, Canada, and involving hundreds of scientists at federal, university, and private laboratories.

During an intensive investigation, the team took tissue samples from hundreds of dolphin carcasses and several live dolphins, as well as from potential prey animals. They analyzed blood and, whenever possible, examined internal organs and stomach contents. Using rigorously controlled experiments, they looked for signs of pollution, viruses, bacteria, and unusual chemicals.

Such pollutants as chlorinated hydrocarbons were present in some specimens, but varied greatly in concentration. Although the researchers isolated several kinds of viruses commonly found in the marine environment, the scientists didn't believe any were sufficiently virulent to be the original cause of the illness in the dolphins. (Nor was there any evidence of the HIV virus associated with the human Acquired Immune Deficiency Syndrome, alleviating an initial fear of dolphin AIDS.) Many strains of bacteria were also identified, but they too were not unusual to the die-off. Geraci and his team theorized that the dolphins were first stressed and weakened by some other sickness, and then became susceptible to bacterial and viral infections.

In early February, after 18 months of research, NOAA announced the team's conclusions. The researchers found the dolphins were poisoned by brevetoxin, a neurotoxin that naturally occurs in tiny marine organisms called dinoflagellates (specifically Ptyochodiscus brevis*) that are responsible for "red tides." NOAA promised to follow up its announcement with a written report from the scientists.*

According to Geraci, of the dolphin livers that the researchers were able to analyze, brevetoxin was found in 50 percent of them, and a probable metabolite of the toxin was found in the other 50 percent. The dolphins would have accumulated the poison by repeatedly consuming plankton-eating fish. The scientists found brevetoxin not only in the viscera of menhaden, a coastal prey fish, but also in one instance in a menhaden inside the stomach of a dolphin. Brian Gorman, a NOAA spokesman, said the team estimates that roughly one-fourth of the dolphins died from direct poisoning, while the rest died from secondary causes.



Hundreds of bottlenose dolphins with severe lesions washed up on the East Coast in 1987/88. (Photo by Charles W. Potter)

"We are certain the dolphin die-off was triggered by brevetoxin," Geraci told Oceanus. *"What is more theoretical is the route by which the toxin was delivered to the dolphins. In 1987,* Ptychodiscus *occurred further north than ever before, causing closure of shellfish beds in North Carolina. Blooms regularly occur in the Gulf of Mexico, but for the first time one persisted through the winter of 1986. We believe a loop current picked up the abundant dinoflagellates and carried them to the east coast of Florida. Plankton-eating menhaden could then have carried the toxin northward during migration."*

Greenpeace, a worldwide conservation group, questioned NOAA's conclusions, and criticized the agency for making a public announcement prior to publication of a scientific report. According to spokesman Brian McKay, "We're not saying brevetoxin could not be involved in the die-off, but we wonder how they can be so certain it's the primary cause. How can they rule out other possibly stressful factors such as high concentrations of pollutants or the increased water temperatures of that period? We'll definitely need to analyze the report thoroughly before we're satisfied." **—SLE**

Individual bottlenose dolphins produce distinct whistles, but also mimic each other. Researchers can distinguish whistles of captive animals by monitoring devices called vocalights (held in place by suction cups), which light up in response to sound. (Photo by Mike Greer, Chicago Zoological Society)

Those Dolphins Aren't Just Whistling in the Dark

by Peter L. Tyack and Laela S. Sayigh

Even though mimicry plays a significant role in the way humans learn language, very few other animals are able to imitate sounds. Marine mammals, however, are an exception. Vocal mimicry is widespread among them. One harbor seal, *Phoca vitulina concolor*, at the New England Aquarium named Hoover learned to produce understandable phrases. Some listeners insisted he had a Boston accent. Humpback whales, *Megaptera novaeangliae*, appear to learn progressive changes in their songs through imitation. Sperm whales, *Physeter catodon*, have been recorded imitating the pulses of a depth sounder. Yet the best data on vocal imitation comes from the bottlenose dolphin, *Tursiops truncatus*.

During the 1960s, a physician and neurophysiologist named John Lilly, working with bottlenose dolphins, noticed that they were remarkably skilled at imitating man-made sounds. If he made three "sound bursts"—for example, by saying "ah" three times—the dolphin made three noises in return. Lilly convinced himself that some of his dolphins could imitate human speech.

To be sure, not everyone who listened to recordings of his dolphins could make out the words that Lilly said he was hearing. But these were the least of his claims. Lilly became so taken with the large brains of dolphins and whales that he concluded that they must have a

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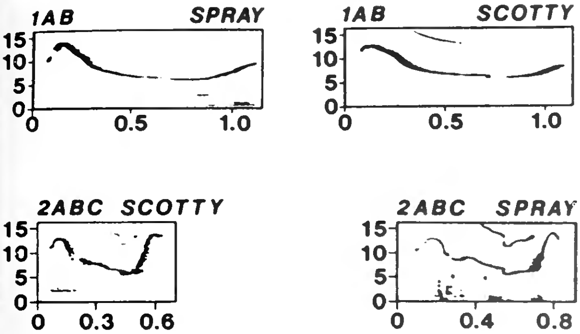
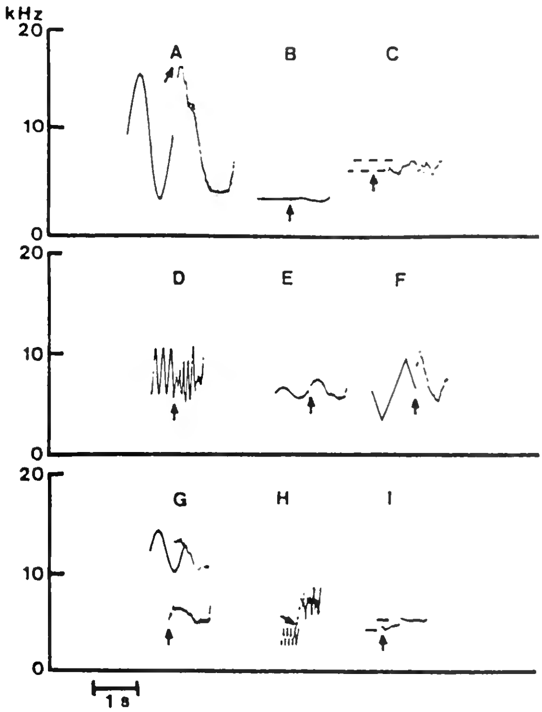


Sound spectrograms of whistles from two captive dolphins, named Scotty and Spray. Vertical axes indicate frequency in kiloHertz, horizontal axes indicate time in seconds. Top left is Spray's signature whistle, and top right is Scotty's imitation of it. Bottom left is Scotty's signature whistle, and bottom right is Spray's imitation of it. (Figure courtesy of the authors)

language as complex as ours, capable of carrying on profoundly deep intellectual exchanges. Of the sperm whale, which has the largest brain of any animal on Earth, he once wrote, "Compared with us, he probably has abilities [in the area of philosophical studies] that are truly godlike."

Such assertions marked the end of Lilly's



Sound spectrograms of nine examples of mimicry by dolphins. The axes are as in the above figure, with the horizontal bar representing one second. In each case the manmade sound is at the left, and the beginning of the mimicry is indicated by the arrow. Often, the mimicry begins even before the model sound ends. (Figure courtesy of the authors)

credibility among most scientists, but not the end of his influence. His books are among the most popular ever written on animal behavior, and have strongly impressed upon American culture the notion that dolphins are more intelligent than other animals, speak a complex language, and could perhaps learn to speak English. His extravagant ideas have been picked up in magazines, books, and films. Carl Sagan, in his book *The Cosmic Connection*, went so far as to suggest that humpback whales sing songs in order to pass down legends in an oral tradition similar to Homer's *Odyssey*.

Studying Animal Language

Ironically, there are few data to counterbalance these popular misconceptions. Scientists were so turned off by Lilly's farfetched claims that for two decades funding remained scarce for studies of dolphin vocalization. During this time, however, other researchers developed experimental studies of "animal language." Their aim was to train animals to use some features of human language to test how well they can master such skills. The most publicized of these studies have involved our nearest primate kin, gorillas and chimpanzees. Although the animals lack the vocal equipment to produce anything like human speech, they have learned to use variations of American Sign Language and other nonvocal forms of communication in language training experiments.

At the University of Hawaii, psychologist Louis Herman has performed similar experiments with bottlenose dolphins. Some of the experiments made use of the dolphin's ability to imitate electronically synthesized sounds, which were broadcast into their pools with underwater loudspeakers. Two of his colleagues, Douglas Richards and James Wolz, along with Herman, even managed to train one of their animals to mimic man-made sounds upon command. Ultimately, they got the dolphin to imitate nine different sounds.

At this point, the researchers realized that they now could study whether the dolphin might actually be taught to associate a specific sound with a particular object and repeat it on command—in effect, to label the object. Trainers held up a ball or a frisbee, say, while at the same time playing its identifying sound. Occasionally they might not play the sound at all, but just hold up the object. Even so, the dolphin still responded with the appropriate sound, showing it remembered the sound that had been paired with the object. Or to put it another way, it was able to learn an arbitrary name for the object and to repeat it.

Communication by Imitation

Successful as these experiments may have been, it would be foolhardy to conclude from them that dolphins are particularly close to humans in what we call "linguistic" ability. Indeed, it's unfortunate that discussions of these studies so often focus on the question of how close animal

language is to human language. It's much more enlightening to concentrate on what specific cognitive, or learning, skills are revealed by an animal language experiment than to engage in fanciful speculation about how similar animals are to humans.

Why, for instance, are humans, dolphins, and many bird species so skilled at vocal imitation while nonhuman primates find this so difficult? The answer may lie in how they use imitation in their own natural systems of communication.

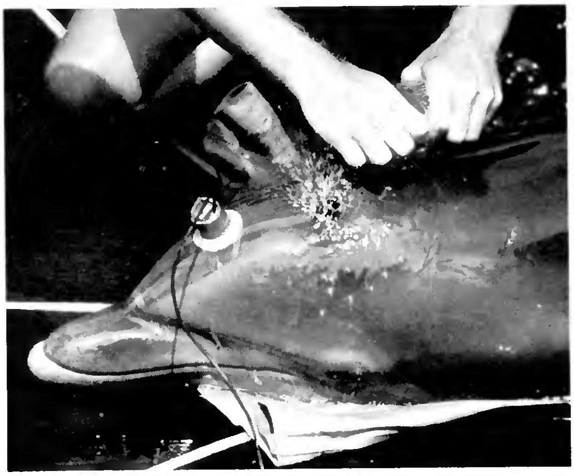
Lilly's claim that dolphins have a language of their own at least as complicated as English ("A possible prototype alien language," he wrote) originated in his study of dolphin whistles. These are short, high-pitched tones that vary in frequency (in contrast to their clicks, which are used for echolocation). Lilly wasn't able to study whistles from undisturbed animals, but he noticed that when three of his dolphins were injured or received an electric shock to the brain, they emitted whistles with a characteristic rise and fall in frequency. Lilly assumed that these whistles were "distress whistles," and that dolphins had different kinds of whistles for different situations.

Subsequently, two French biologists, René Guy Busnel and Alban Dziedzic, analyzed hundreds of "distress whistles" from a dolphin in the wild that had been harpooned and caught. All these whistles were similar in structure, that is, they displayed the same shifts of frequency over time. This certainly didn't indicate the existence of a complex whistle language, and the French biologists decided that there must be two different types of dolphin distress whistles, theirs and Lilly's.

In 1965, two California researchers, Melba and David Caldwell, proposed an alternative interpretation of dolphin whistles based upon an analysis of individual dolphins within a captive group. The Caldwells found that each dolphin tended to produce strikingly distinctive whistles. This led them to hypothesize that one of the functions of these "signature" whistles was to broadcast the whistler's identity to other members of the group.

Even before the Caldwells' pioneering work, however, other studies had shown that dolphins use whistles to establish vocal or physical contact among themselves. The studies found that captive dolphins whistle when they are separated from group members, and respond to whistles either by whistling themselves or by approaching the whistler. Female dolphins and their young calves, especially, will exchange whistles until they are reunited.

Clearly, social relationships are very important in both captive and wild dolphin societies: limited in the visual contacts that are possible under water, dolphins use their signature whistles to communicate. Thus, even when other animals in the group are also whistling, a mother and calf, for instance, can use their signature whistles to find one another.



Hydrophones on restrained wild dolphins have shown that closely bonded individuals imitate each other's whistles while separated. (Photo by Peter L. Tyack)

Signature whistles may have other social functions as well, but it has been difficult to identify their purpose because it's so hard to tell which dolphin is whistling. To help overcome this obstacle, one of us (Tyack), as a postdoctoral scholar at the Woods Hole Oceanographic Institution (WHOI), developed a small telemetry device called a vocalight, which is attached to a dolphin's head with a suction cup. Every time the dolphin produces a sound, the vocalight lights up. Moreover, the louder the sound, the more lights flash, somewhat like the light displays on the control panel of a stereo amplifier.

The vocalights are made in a variety of colors. If several animals are in a pool, each can be equipped with a vocalight that produces a different color. To identify which dolphin has made a particular sound, a poolside observer simply calls out the color displayed at that moment. Both the whistles (picked up in the water with a hydrophone) and the observer's identification of the colors are recorded simultaneously for later analysis. (If two dolphins happen to whistle simultaneously, you eliminate these cases from the data.)

The Interactions of Scotty and Spray

The vocalights were first used with two captive dolphins named Scotty and Spray at Sealand, a marine park in Brewster, Massachusetts, on Cape Cod. Here the dolphins could be studied while they were interacting, rather than swimming in isolation, as had been typical for those studied by the Caldwells. Both Scotty and Spray produced a stereotyped whistle very much like the signature whistles described by the Caldwells. Both also produced whistles almost identical to the presumed signature whistle of its poolmate. We asked ourselves whether this wasn't a hint as to why dolphins have developed such impressive skill at vocal imitation.

A possible answer comes from studies of a

community of wild bottlenose dolphins off Sarasota, Florida, that Randall Wells of the University of California at Santa Cruz and WHOI has observed for more than 18 years. By using their external markings to identify individual dolphins, Wells was able to study patterns of association among the animals. As might have been expected, he found that mothers and calves have very strong bonds. They were sighted together for at least three to six years. More surprising was the strong bond discovered in adult males. Some pairs or even trios were spotted together in nearly every sighting over many years.

For the last few years, we've been working with Wells, supplementing his visual sightings of the dolphins with acoustic studies of their whistling. This has been done by temporarily corraling the dolphins in a net and placing suction cup hydrophones on them. Because the hydrophones transmit the sounds they collect by wire rather than by radio, the dolphins must be kept confined during our recording sessions. We record the animals while they're being held in the water or in a raft. When the dolphins are restrained in this way, mothers and calves, or strongly bonded males, are sometimes held out of sight of each other. In these cases, we found that stereotyped whistle exchanges continued until the partners were reunited.

Mystery of Male Bonding

While the advantages of bonds between mothers and calves are easily understood, the reasons for strong bonding among adult males are more obscure. However, data from Wells' project and from observations of *Tursiops* in Western Australia (article, pp. 76–78) both indicate that by bonding, males have a greater chance of mating with females than if they were alone. In his present research, one of Wells' major objectives is to explore the degree of relatedness in these males through DNA-fingerprinting and chromosome banding.

In our current research, we are trying to determine in what circumstances a dolphin produces its own signature whistle or imitates the whistles of others. (Signature whistles account for more than half of the whistles.) There are various possibilities. Perhaps untrained dolphins imitate the signature whistle of another group member to initiate a social interaction with that dolphin. Perhaps the males imitate the signature whistles of their partners in order to maintain contact with them or even to call them.

Our observations in Sarasota show that the males tend to imitate the whistles of animals with which they already share a strong bond. Thus by imitation, the dolphin appears to be signaling a specific individual, rather than merely signaling other dolphins that happen to be nearby. And it may be a variation of this ability to "label" other dolphins that Richards and his colleagues observed in their Honolulu vocal labeling experiment.

Beyond explaining certain aspects of dolphin behavior, there may be more general lessons from this work. When field biologists study animal behavior, they often have difficulty finding common ground with experimental psychologists, and vice versa. That's a pity because the approach of each group toward animal cognition has many strengths, which in isolation become weaknesses.

Experimental psychologists can often identify cognitive skills very precisely in lab experiments, yet their results may be difficult to interpret in light of the animal's behavior in the wild. By contrast, field biologists can frequently explain why certain traits evolved by comparing different species in different environments, but they're so impressed with the power of natural selection to shape particular behaviors that they tend to forget that animals may have developed general abilities for learning to solve the problems presented by their way of life. It's only by shuttling back and forth between experiment and field study that we can hope to understand the full complexity and diversity of animal cognition.

The work of Richards and coworkers, for instance, led us to consider that dolphins might imitate signature whistles in order to call another individual. Conversely, our results on the imitation of signals may help experimental psychologists understand the functions in nature of cognitive skills they've uncovered in the laboratory. □

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Watching the Whales:

Is an educational adventure for humans turning out to be another threat for endangered species?

The explosion of whale watching is raising concern about its effects on the animals. (Courtesy of Cetacean Research Unit)

by Douglas W. Beach and Mason T. Weinrich

Two whales surface ahead of our vessel. Their shimmering "blows" hang over the cold ocean like morning dew. Their flukes, silhouetted against the sky as the whales begin to dive, identify them as a pair of humpbacks, *Megaptera novaeangliae*. In the distance, we spot the tall blow of a fin whale, *Balaenoptera physalus*, the second largest of the whales (after the blue, *B. musculus*). Another group of whales passes close to a trawler that ignores the animals while slowly dragging its gear.

Completing a quick scan of the horizon, we observe a large freighter steaming through the area and a sport fishing vessel approaching from the west. The sport fisherman, attracted by the commotion, heads straight for the whales as they return to the surface. Once again the whales dive slowly, showing no apparent concern for the vessel bearing down on them. The sport fisherman drifts over the very spot where the whales have disappeared, coming to a stop only shortly beyond it. The whales surface several more times as we stand by, watching their every move, and then they leisurely swim off toward a distant group of humpbacks.

Such scenes are now a common occurrence off the Atlantic and Pacific Coasts. From Eastport, Maine, to Montauk, New York, and from Seattle to San Diego, as well as more distant sites such as Hawaii, throngs of people are heading out to sea almost daily, eagerly anticipating an encounter with the great marine mammals. For most, the trips are a rare wildlife experience as well as an environmental conciousness-raising, but as thrilling as whale watching may be for humans, there is a more serious issue: What is its effect on whales, some of them only now recovering from years of uncontrolled hunting?

No clear-cut answer is yet possible, but certainly there are legitimate concerns for the well-being of some species in certain areas. Most of our experience is on the eastern seaboard, and so our discussion will center on this region.

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In 1975, the presence of many large whales feeding in waters off New England was "rediscovered," leading to the birth of commercial whale watching there. The first skipper in New England to take people out to see the whales was Captain Al Avellar, owner of the charter deep-sea fishing boat *M/V Dolphin III*, out of Provincetown, Massachusetts, at the tip of Cape Cod. Other charter operators followed in his wake, either on a full- or part-time basis. Whale watching soon became a multimillion-dollar business on the East Coast. In Massachusetts and New Hampshire alone, at least 21 companies now rely on whale-watching tours for all or a substantial part of their income. Whale watching has become one of New England's major attractions.

The sight of a breaching humpback whale is cherished by whale watchers. (Courtesy of the authors)

As Many as Three Trips a Day

Typically, the vessels are 65 to 100 feet long, powered by diesel engines, and have space for 100 to 150 passengers. Most are party boats either specifically designed or modified for whale watching. From April to October, many make two trips a day; at the height of the summer some go out as many as three times a day. The trips usually last four to five hours, although full-day excursions are necessary from ports at greater distances from the whale grounds.

Most vessels bring along a naturalist who provides a running commentary not only about the whales but about the history and biology of the area. When a whale is spotted, the naturalist identifies the species, describes its behavior, and discusses its characteristics. We've found that participants usually leave a whale watch with a greater appreciation of whales, whale conservation, and the overall marine environment.

New England whale-watching companies concentrate on Stellwagen Bank and Jeffrey's Ledge. Stellwagen Bank stretches from 12 miles southeast of Gloucester to six miles north of Cape Cod, a length of 21 miles. The bank's average depth is 90 to 100 feet, with surrounding depths of up to 450 feet. Jeffrey's Ledge starts five miles northeast of Cape Ann and extends to southern Maine. Water depth ranges from 150 to 550 feet.

Within easy reach of vessels from Provincetown to York, Maine, these areas are often host to large populations of humpback whales, fin whales, minke whales, *Balaenoptera acutorostrata*, and Atlantic white-sided dolphins, *Lagenorhynchus acutus*, all of which return each summer. Occasionally northern right whales, *Eubalaena glacialis*, are sighted in the spring on their way to feeding grounds in the lower Bay of Fundy and on the Scotian Shelf off Nova Scotia.

Most whale species migrate annually between summer feeding grounds in temperate waters and winter breeding grounds in the tropics. The low plankton productivity of the tropics supports few fish for the whales to feed on. So the whales, during their four- to five-month winter fast, must live off their blubber, resulting in a weight loss of up to 20 percent. By the time they return to New England waters, they're ready for a feast. Humpbacks, fins, and minkes prefer sand lance, herring, and mackerel. They'll also take some euphausids, or krill, when available.

The same group of humpback whales returns every year to New England waters. Its summer range spans the coast from Long Island to Nova Scotia, although individual animals, which are identified by natural markings, seem to show an unusually high degree of site fidelity. For at least part of the summer, they'll usually return to a specific area, either Stellwagen Bank, Jeffrey's Ledge, or the Great South Channel, southeast of Cape Cod. The same fin whales also return annually to the region, although the affinity of individual fins for specific locales seems far lower than that of humpbacks.

A Tolerance for Traffic

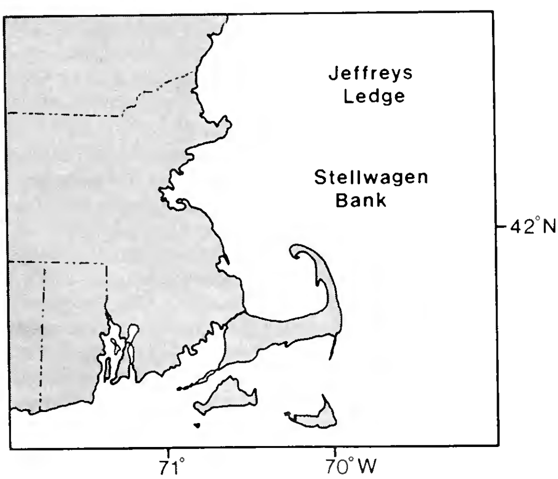
During their stay in New England waters, whales are exposed to many human activities, of which whale watching is only one. Provincetown, Boston, and Gloucester are all home to large commercial fishing fleets, which trawl and gillnet for groundfish in areas important to whales, as well as purse-seine there for herring. The highly prized bluefin tuna is a target of both commercial and recreational fishing each summer on Stellwagen Bank, where "floating cities" of more than 100 vessels may be seen within a two-mile radius. And passing through both Stellwagen Bank and the Great South Channel are the major shipping lanes to and from Boston.

The whales of New England clearly have become tolerant of these activities. Even amid

the area's heaviest traffic, the humpbacks form large aggregations. By contrast, the humpbacks off southeast Alaska, another important feeding area, appear sensitive to a much lower level of traffic. The varying reactions of the whales in the two places may be partly attributable to differences in the sites. The southeast Alaska feeding area lies in hard rocky basins that may reflect and/or magnify vessel noise, whereas the open waters and sandy bottom of Stellwagen Bank are more likely to disperse and absorb sound. Also, most of the vessels affecting whales off Alaska are large cruise ships that generate more noise than the smaller New England whale-watching vessels.

Regular exposure to passing vessels may, in fact, be the most important component of a population's tolerance of whale watching. Migratory California gray whales, *Eschrichtius robustus*, experience a significant amount of whale watching at their birthing sites in the lagoons of Baja California, as well as commercial fishing and shipping traffic all along the West Coast; therefore their acceptance of vessel activity appears to be high in spite of the fact that the Soviet Union permits a low level of hunting in the North Pacific. On the other hand, North Pacific humpbacks encounter very little vessel traffic either in their Alaskan feeding areas, or to and from the Hawaiian breeding grounds. In addition, the natural movement of individual whales through the breeding grounds minimizes their exposure to the intense coastal traffic near certain islands. This may explain why this population has not developed the vessel tolerance seen in the New England humpbacks and California gray whales.

Our experience in New England indicates that commercial whale watchers usually comport themselves well. Their captains know how to work around whales in a manner least likely to disturb them and usually do their best to follow the vessel operation guidelines developed for the



New England whale-watching companies concentrate on Jeffrey's Ledge and Stellwagen Bank.


The Cetacean Research Unit's Silver II *and a humpback. (Photo courtesy of the Cetacean Research Unit)*

region. However, operators less experienced or knowledgeable about proper boathandling near whales may present a problem. In the few documented instances of collisions between whales and boats, irresponsible maneuvering by the vessel has been implicated.

When uninformed boaters approach whales aggressively, cut in front of them, box them in, or move over feeding spots, whales may signal their annoyance by abruptly changing direction or breaking off their activities. Engine noise is the main irritant. We've observed that the high-frequency sounds of the outboard engines of smaller private boats are as likely to disturb whales as the lower-pitched rumblings of the diesel engines in larger vessels.

The task of researchers and managers concerned with the well-being of whales is to determine what effect, if any, whale watching and other vessel activities have on these endangered species. However eager the public may be to view them in their natural setting, whale watching is justified only if the animals are able to feed, rest, or otherwise achieve the maximum benefit from their chosen habitat.

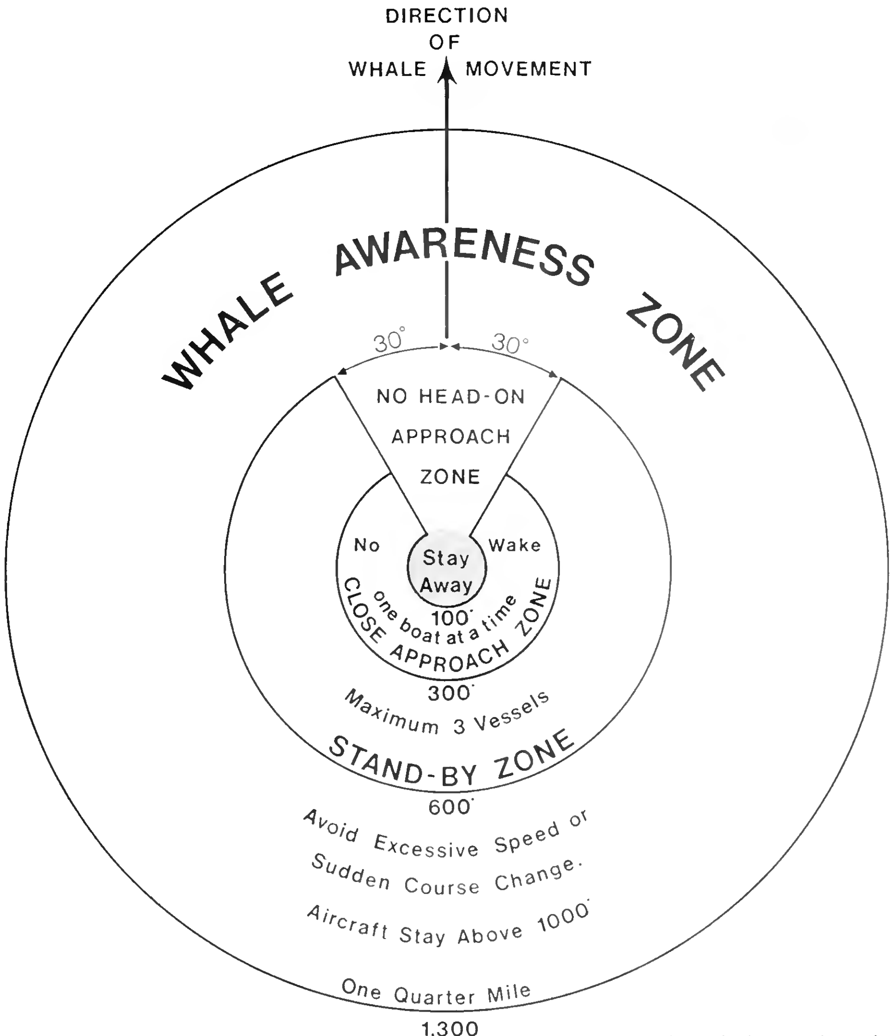
What Is Harassment?

Both the Marine Mammal Protection Act of 1972 and Endangered Species Act of 1973 protect whales and their habitat. The National Marine Fisheries Service, an arm of The National Oceanic and Atmospheric Administration (NOAA), is responsible for the enforcement of both acts within the 200-mile limit. The laws specifically prohibit "harassment" of whales, but what constitutes harassment, especially by vessels near whales? Federal regulations define harassment as "any intentional or negligent act which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns."

This definition seems adequate for any case where a vessel obviously threatens injury to a whale; and given appropriate enforcement effort, the whales' physical safety could be reasonably protected under the statute. However, most whale-vessel interactions don't cause direct physical injury. Rather they produce avoidance behavior by the whale (sudden dives, for exam-

(continued on page 88)

Whale Watch Guidelines



To protect whales and their habitat, and promote public awareness of the need to avoid harassment of whales, NOAA Fisheries provides the following guidelines for vessels in the vicinity of endangered whales in the Gulf of Maine.

A. WHEN IN SIGHT OF WHALES (LESS THAN 1,500 FEET AWAY):

- *Avoid excessive speed or sudden changes in speed or direction.*
- *Aircraft observe the FAA minimum altitude regulation of 1,000 feet over water.*

B. CLOSE APPROACH PROCEDURE (LESS THAN 600 FEET AWAY):

- *Approach stationary whales at no more than idle or "no wake" speed.*
- *Parallel the course and speed of moving whales.*
- *Do not attempt a head-on approach to moving or resting whales.*

C. MULTIVESSEL APPROACH (LESS THAN 300 FEET AWAY):

- *All vessels in close approach stay to the side or behind the whales so they do not box in the whales or cut off their path.*
- *When one vessel is within 300 feet, other vessels stand off at least 300 feet from the whale.*
- *The vessel within 300 feet should limit its time to 15 minutes in close approach to whales.*

D. NO INTENTIONAL APPROACH (LESS THAN 100 FEET AWAY):

- *Do not approach within 100 feet of whales.*
- *If whales approach within 100 feet of your vessel, put engine in neutral and do not re-engage props until whales are observed at the surface, clear of the vessel.*

Active whales require ample space. *Breaching, lobtailing, and flipper-slapping whales may endanger people and/or vessels. Feeding whales often emit subsurface bubbles before rising to feed at the surface. Stand clear of light green bubble patches.*
In all cases, *do not restrict the normal movement or behavior of whales, or take actions that may evoke a reaction from whales or result in physical contact with a whale.*
Diving *on whales is considered to be an intentional approach of whales and may be considered a violation of federal law.*

A humpback's snout shows characteristic bumps called stove bolts. (Photo by Karen E. Moore)

(continued from page 86)

ple), or changes in such activities as feeding, resting, or socializing. In these circumstances, it becomes more difficult to assess a vessel's effect on whales.

Humpback, gray, and bowhead whales show obvious and universal reactions to certain human intrusions. Investigations in the Arctic Ocean and off Hawaii, California, and Massachusetts found that whales generally avoid approaching boats and low-flying aircraft by increasing their swimming speed, orienting away from the disturbance, and decreasing the amount of time spent at the surface between dives. Yet to determine if a whale is responding to a specific vessel, one must identify other environmental stimuli that may also influence the whale's behavior. This has turned out to be very difficult, if not impossible, to do.

The ideal solution to the issue of what constitutes harassment would be to find one unequivocal whale behavior or behavioral display that clearly indicates disturbance. But here, too, none has yet been identified, even after the whale is subjected to such irritants as the implantation of a radio tag or use of a biopsy dart to obtain a skin sample. What's more, behaviors often associated with disturbance, such as trumpet blows (wheezes) and tail slashes, are also components of social displays.

Ensuring the physical safety of the whales is a matter of prime consideration under any protection policy. But is even this enough to ensure the species' long-term survival and ultimate recovery from its endangered status? If it isn't, additional measures may be required, as those imposed in Hawaii, where NOAA Fisheries has identified humpback breeding and calving areas and forbidden any approach by a vessel closer than 100 yards of a whale.

However, in New England and other whale-watching regions, there's no evidence that the humpback and fin whales require similar protection. Nonetheless, NOAA Fisheries feels it's important to educate the public about ways to behave in the vicinity of these species. In a brochure entitled *Whales of the Gulf of Maine*, developed in cooperation with whale-watch operators, marine mammal researchers, and environmental groups, it provides guidelines for the safe operation of vessels near whales (box, page 87). They are designed to foster an increased awareness of a whale's needs, especially its space requirements, as it is approached by whale watchers.

Because it's virtually impossible to keep a constant vigil on the region's feeding grounds, voluntary public cooperation is important. Indeed, the majority of "harassment" cases are reported to NOAA Fisheries by private citizens. If there isn't enough evidence—for example, photographs or knowledgeable witnesses—for an enforcement action, which is usually the case, the vessel's operator/owner is sent a letter saying that it may have acted improperly around an endangered species. A copy of the brochure is enclosed. This approach puts vessel operators on notice and seems to be working well.

Protection Is Only Short-Term

Concerns over whale watching were aired at a workshop sponsored by NOAA Fisheries and the Center for Environmental Education, in Monterey, California, last November. Even in the absence of conclusive scientific evidence about the effects of ship traffic on whales, the conferees felt that setting minimum approach distances would strengthen the hand of enforcement officials. Workshop participants also recommended additional research characterizing the acoustic environment in each region, and determining the long-term effects of whale watching on the health of whale populations by monitoring demographic changes such as calving rates, mortality, habitat use, and migration.

Whale-watch regulations can only protect whales in the short term. To guard against the long-term degradation of their habitat, which could be a more serious threat, NOAA Fisheries has established "recovery teams" to direct future conservation efforts for humpback and right whales. These teams are developing plans for further assessment of the impact of human activities on whales in busy areas such as New England. Recommendations could be made to protect key areas under the "critical habitat" provisions of the Endangered Species Act.

Whale conservation is a dynamic process involving many people working toward a common goal—to maintain and enhance the health of existing whale populations. The continued use of New England's waters by whales is very important to the people of the region, both as a tourist attraction and as a sign of the overall health of the marine environment. We must make sure that there are no irreversible changes against the interests of any of their current users—human, fish, or whale. □

The Lost Whales of Tierra del Fuego

Crania of 22 pilot whales, from a stranding at the easternmost tip of Tierra del Fuego. (All photos by the author)

by R. Natalie P. Goodall

As a born beachcomber, I've always collected things—flowers, stones, driftwood, shells. For the last 12 years I have collected bones, and stored them in the garage, on the living room rafters, on the top guest room bunk, in the nearby research center, in the local museum, and at the farm (*estancia*) managed by my husband, Tom, in Tierra del Fuego, at the tip of South America. Not just any bones, but those of dolphins, porpoises, rare beaked whales, and even a few sperm and baleen whales. My collecting isn't a hobby. It's a full-scale, ongoing, long-term research project.

I wasn't always interested in cetacean bones. First I was a teacher in the United States and Venezuela, then I met my husband in southernmost South America and came to live on a farm on the Beagle Channel. I used my degrees in biology to collect and illustrate the native flora of Subantarctic Tierra del Fuego, my new home. I searched for rare plants in the forests, the mountains, and the swamps, and on the beach. While walking along the beach, I picked up some strange skulls. They were the remains of dolphins or porpoises, but knowing nothing of such things, I stored them in cardboard boxes in my unfinished garage in Ushuaia.

Meanwhile, two pilot whales, *Globicephala melas*, had beached at Harberton, the family *estancia*. I wrote to the author of a children's whale book to find out what they were, and thereby met my first whale mentor, Kenneth S. Norris, of the University of California at Santa Cruz, who still leads my cheering section. He sent me books and introduced me to William E. Schevill, of the Woods Hole Oceanographic Institution, who sent more information.

A few years later, several whale experts, including Robert L. Brownell, Jr., (article, pp. 5–11) and Edward Mitchell of the Canadian Arctic Biological Station, actually came to Tierra del Fuego on a whale observation expedition. I showed them my skulls. They were astounded, holding the skulls gingerly in their hands. I was told they were *Phocoena dioptrica*.* There are

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Rae Natalie P. Goodall, a self-taught marine biologist from Ohio, has lived in Tierra del Fuego, Argentina, since 1963, collecting and investigating the cetaceans that have stranded there. She is the author of a guide, Tierra del Fuego*, and several maps on the region. She is an* investigador independiente *of the* Consejo Nacional de Investigación Cientifica y Técnica *in Argentina and a research associate of the Long Marine Lab of the University of California of Santa Cruz and the* Museo Argentino de Ciencias Naturales Bernardino Rivadavia *of Buenos Aires.*

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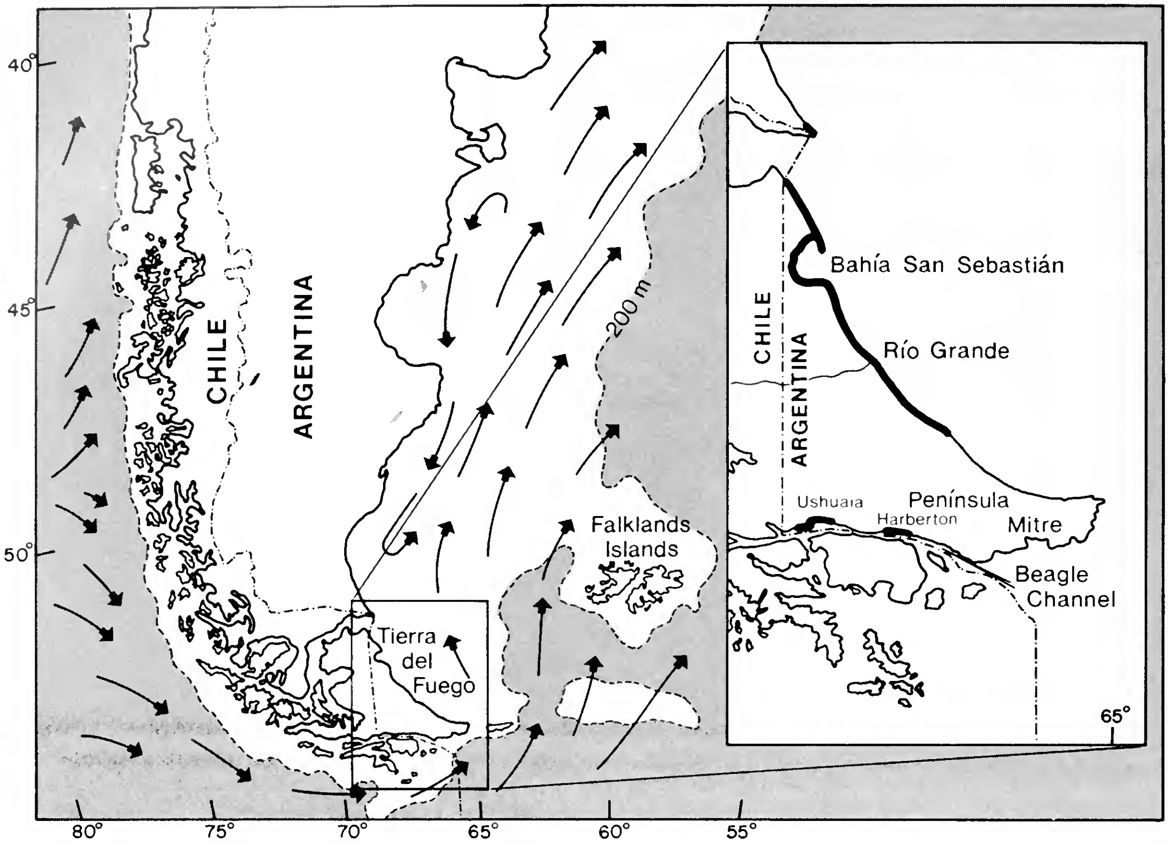
* Now called *Australophocaena dioptrica.*



Major currents off southern South America. Inset, eastern Tierra del Fuego. Coasts surveyed for strandings are darkened.

only six or seven of these in the whole world, and none in any museum in North America. Unknowingly, I had tripled the world's supply of these rare specimens.

If something is that rare, it is worth going out to look for some more. My first trip was with future Argentine cetologist Hugo Castello in 1974; as greenhorns, we misidentified nearly everything. The first real bone-collecting expedition took place in 1976. Again, unwittingly, I chose the best spot, the southwest corner of Bahía San Sebastián in the northern part of Argentine Tierra del Fuego. On a five-mile stretch of gale-swept beach, we found 88 specimens, though not all of them were complete. I soon learned that any new beach will produce lots of old, weathered, dismembered skeletons, and that certain places—shallow bays with wide shelving beaches, sandy bays near river mouths—produce more bones than other areas. Of course, carcasses that drift ashore onto rocks or at the base of cliffs are soon broken up and taken by the tide. The wide mud flats and high tides of San Sebastián have made it one of the major stranding areas of the world.

My bone collecting picked up when an Australian hitchhiker, Ian Cameron, came by one day and stayed for two years, developing most of our collecting and curating methods. A short time later, cetologist James G. Mead of the Smithsonian Institution arrived on a tourist ship and rushed over to my house to spend several hours identifying bones we had spread out everywhere, while I took down every word. By then we had specimens of about 15 species of smaller cetaceans. In the end, he said, "Only two museums in the world, the British Museum and the Smithsonian, have at least one specimen of each genera of the beaked whales. Now there is a third" (my small basement laboratory).*

Things seemed almost preplanned. I had met the cream of the crop, the world's most respected cetologists. Soon I was in contact with dolphin-bone specialist William F. Perrin of the National Oceanic and Atmospheric Administration Fisheries Service. Southern hemisphere experts Peter Best and Graham Ross of South Africa, Alan Baker of New Zealand, and Ricardo Praderi of Uruguay completed my advisory committee. Most of them began their research in other scientific disciplines. Most were self-taught in cetaceans through reading and their own experience. I began on the same trail, seriously collecting specimens, taking down data, and reading. The nearest adequate library was 3,000 miles away, in Buenos Aires, and it carried few

* This statement is no longer true, but it was in 1978.

recent publications. So I built my own library from scratch, buying books and subscriptions, but mainly through thousands of photocopies from people in more civilized places. Sometimes I had to wait months for a particular reference.

I decided to limit myself to the relatively unknown smaller cetaceans, because the large whales of this area had been and still were under intensive study.

Why Tierra del Fuego

Since the early scientific expeditions around the Horn, only a few of the great 19th-century multidisciplinary naturalists, such as R. A. Philippi in Chile, and G. Burmeister and F. P. Moreno in Argentina, had published on the smaller cetaceans of southern South America.

Furthermore, Tierra del Fuego is the southernmost regularly inhabited part of the world, sticking well down into the Southern Ocean toward Antarctica. At its latitudes, 52 degrees 30 minutes South to 56 degrees South, there are no other major land masses clear around the world. There is little shipping, and even if there were, certain smaller cetaceans are rarely seen in their natural habitat, the sea. Some species are known only by a few specimens stranded on the handful of beaches in the Subantarctic. This was new territory, and perhaps some of the "rare" species might not be so rare here. And that is exactly the way it turned out.

The archipelago of Tierra del Fuego is a mass of islands and channels, inhabited only to the north and east and whipped by gale-force winds much of the year, predominantly from the southwest. The currents have not been well studied, but, in general, sweep around Cape Horn from the southwest (the West Wind Drift) to head north-northeast as the Falklands, or Malvinas, Current. Both the Beagle Channel, where we live, and the Strait of Magellan flow eastward; bones on the northeast coast of the Isla Grande move southeastward with the tides. The continental shelf off southeastern South America is very wide and shallow, probably providing many prey species for the smaller toothed whales. The shelf outline shows up as a major area of phytoplankton production on a new (1988) satellite sensory map by the National Geographic Society.

Bahía San Sebastián has a wide (nine-kilometer horizontal distance between maximum tides), sandy, shelving beach with deeper trenches leading shoreward and exceptional tides (a maximum of about 10.8 meters). According to Joseph R. Geraci, all of these factors are ideal for producing strandings (*Oceanus*, Vol. 21, No. 2, pp. 39–47).

Getting Down to Work

When we began to look for stranded cetaceans, organized stranding programs were just being developed in the United States, although they had been under way in England for more than 60 years. Most stranding programs, then and now, in other parts of the world are passive; researchers are on call if someone reports a stranded animal on a beach. Only a few people go out on beach patrols. In Tierra del Fuego, where the beaches are cold, windy, and isolated, we set out to look for stranded animals ourselves.

With a vehicle from a National Geographic grant and camping gear, we headed for the northern coasts, a five- to seven-hour drive from Ushuaia, and began walking the beaches. We found lots of material. Entire or decomposing animals had to be left on the beach—there was no way to get them out. (One beachcomber brought us all the tags we had left to identify animals in a certain area.) Cleaner bones could

A young male sperm whale stranded on the mud flats of Bahía San Sebastián in 1977.

be taken in a pack or dragged out to a road. The business was laborious and time-consuming, and we developed strong legs and backs trudging in sand and the famous Patagonian shingle (miles of small, rounded stones that slide with each step).

Each of my advisors sent me his methods and forms for taking data, usually printed on nice sheets of 8- by 10-inch paper. But the paper wouldn't last a minute in our wind (never open two doors of the truck at the same time), so we developed our own data sheet, on lightweight cardboard, with all the data on one folded piece of paper, strapped down on a wooden clipboard.

Since we had no wet lab, all our dissections were carried out on the beach or in my backyard, often in fierce sand or rain storms. We followed standard procedures for taking photographs of pigmentation, measurements, teeth for aging, organ weights, parasites, stomach contents, and retrieving the skeleton. A vast amount can be learned from a stranded animal, especially if it is a fresh specimen. But even with monthly or bimonthly surveys, most carcasses were no longer fresh or even had flesh on them. Gulls and petrels can flense a dolphin

in a few hours, but won't touch certain other species. Many animals were highly decomposed, but you get so interested in what you're doing that you forget the smell.

Long-dead remains might reveal the first record of food habits (the stomach contents) of a rare species. Often stomachs are empty. After hours of cutting into a very pungent killer whale, *Orcinus orca*, we found that the voluminous stomachs contained only five small black pebbles. Often a careful search will reveal a pelvic bone, the shape of which tells us the sex.

In 1980, a new assistant, Alejandro Galeazzi, entered the program. We obtained two small sheds from the state oil company, YPF, and installed a primitive field camp at Bahía San Sebastián. When the first all-terrain cycles (ATCs) arrived in Tierra del Fuego, we took one look and decided they were for us. They can go almost anywhere, except deep sloshy mud, and carry or drag a surprising amount of bones.

Even with ATCs, however, many beaches are inaccessible. Once, while we were trying to get down a steep slope to the beach, the ATC flipped over seven times and we spent two days getting it out and repaired. From 1979 to 1981, the Argentine Navy let us survey certain beaches with its helicopters. On two occasions the government of Tierra del Fuego took us to a spot where a whale had been sighted. We surveyed the most inaccessible areas in eastern Tierra del Fuego and Isla de los Estados from the National Science Foundation's ships *R/V Hero* and *Polar Duke*.

In 1982, the *Centro Austral de Investigaciones Científicas* (CADIC) opened in Ushuaia, the most southerly town in Argentina, with a population of 50,000. I was given an office, which soon filled with skeletons, and a wet lab to necropsy small, fresh dolphins. There was (and is) no freezer to store animals.

Taking care of the specimens took a lot of time, and a series of Argentine and foreign students helped each summer. Although many experts collect only skulls, we are interested in dolphin growth, development, and diseases, so we keep the complete skeleton of each specimen and even individual isolated bones.

From the beginning we cleaned our skeletons by maceration (soaking in water) or simmering them in a opened oil drum in my back yard in Ushuaia. The specimens must be cooked carefully so as not to loose any teeth (those for determining age were removed previously), or the tiny bones of the tail and flippers. Anyone downwind could tell when we were bone-boiling. Now, with the growth of the town, backyard cleaning is no longer feasible, and new facilities are being constructed at the *estancia*.

After cleaning, we wire the vertebral column in sections (cervicals, thoracics, lumbars, caudals), number each bone, and store each specimen in a cardboard box. We printed up lots of sighting forms and gave them to any ships visiting the area. Soon the sightings started to roll in. We often saw animals from the coast and

Checking the teeth of a killer whale stranded on the Bahía San Sebastián coast some four years previously.

tried a five-month shore-based observation program for coastal dolphins, but this was discontinued, mainly because a beachcomber typically looks down rather than out to sea.

The Findings

Our specimens arrive in four ways: floating dead animals that drift ashore, those that come ashore alive, smaller animals caught accidentally in fixed nets set for fish, and a few harpooned deliberately as bait for crab traps. The first question everyone asks is why whales strand. There are many papers on that subject and, in the end, no one really knows.

We feel that many animals are trapped in shallow water by the rapidly falling tide at Bahía San Sebastián, but we don't know what they were doing there in the first place, or what prey species might be in the bay. Usually we have no way of telling if the animal arrived alive or dead. I have seen only three live strandings: two pilot whales trapped in mud (my first two specimens), and one juvenile porpoise found on the beach, but have been told of eight other live strandings. Three were sperm whales (*Physeter catodon*), one a minke whale (*Balaenoptera acutorostrata*), one a pilot whale, and three Risso's dolphins (*Grampus griseus*). Two were reportedly chased ashore by killer whales, and one sperm whale was wounded. Several times we have seen floating carcasses: seven sei whales, *B. borealis*, in 1965, and one minke whale in 1988.

Fixed nets set from the shore for fish on tidal flats account for many specimens of the smaller coastal dolphins and porpoises. Again, we do not know exactly how many were trapped in nets because the fishermen often leave the dead dolphin on the mud flats and it floats ashore elsewhere. Some fishermen save incidentally caught animals for our study. And in 1978, we obtained seven Peale's dolphins, *Lagenorhynchus australis*, which had been deliberately harpooned for crab bait, a problem

of unknown proportions in southern Chile and on the Beagle Channel.

These strandings and captures give us information on the distribution of species—if there are no animals out there, they can't strand (although a few carcasses may be brought some distance by currents). But they don't give a complete picture, since some species may not strand at all. Moreover, the proportions of strandings do not reflect relative proportions of species in the sea.

Subantarctic Cetaceans

Most marine mammal stranding programs can tell immediately which species are represented by what percent of strandings. This is more difficult for us, because we collect postcranial skeletons and individual diseased bones, that might belong to a skull we collected earlier, later, or somewhere else along the beach. Not all specimens represent a whole animal. Therefore, specimens are detailed as cranial or postcranial, the latter including mandibles found alone (Table, page 95).

In 12 years, we have collected 1,435 specimens, 1,333 (92.9 percent) of which are cetacean, 84 (5.85 percent) are pinnipeds of six species, and the rest miscellaneous (fox, beaver, guanaco, human) skulls.

Of the cetacean remains, 78.7 percent were smaller cetaceans (excluding the minke whale) and 6.5 percent large whales; the remainder, mostly large individual bones, have not yet been studied. Cranial material accounted for 59.5 percent of the total cetacean specimens.

LARGE WHALES. Tierra del Fuego is on the Antarctic migration route of most of the larger whales—the blue (*Balaenoptera musculus*), fin, (*B. physalus*), sei, minke, humpback (*Megaptera novaeangliae*), southern right (*Eubalaena australis*), and sperm. Although large whales are not our prime interest, we take photographs, measurements, and samples of teeth, baleen, and earbones. We have identified 71 cranial and 16 postcranial specimens of these whales. Sperm whales accounted for 61 specimens; measurements and teeth were taken from 44 animals in four mass strandings of young males (7, 18, 11 and 8 individuals), and of three single strandings of larger males. We have data on 11 minke, and nine sei whale strandings.

SMALLER CETACEANS. When our program started, we could find reference to only nine species of smaller cetaceans occurring near Tierra del Fuego. We now have specimens of 21 species, 31.8 percent of the 66 known in the world. Four families are represented in Tierra del Fuego: the Delphinidae (71.9 percent of the 680 cranial specimens), the Phocoenidae (21 percent), the Ziphiidae (6.9 percent), and one individual of the Neobalaenidae, the pygmy right whale, *Caperea marginata*.

The species with most individuals in the collection are the Commerson's dolphin, *Cephalorhynchus commersonii* (51.5 percent of the Delphinidae and 37 percent of the total crania), and the spectacled porpoise, *Australophocaena dioptrica* (93.7 percent of the Phocoenidae and 19.7 percent of total crania).

The majority of the Commerson's dolphins died in nets. These small, lively black and white dolphins feed in the breakers on the rising tide, so they are particularly susceptible to nets set across their path on the tidal flats. Many of the specimens were fresh (one was alive), giving us ample information on pigmentation, size, age, and food habits. Young males (out exploring?) were most frequently caught, but both sexes and all age groups are represented. Most animals were healthy with few parasites. The sexes could be easily distinguished at a distance by their black genital patches. Markings on the head and

Alejandro Galeazzi and helper checking tags on a 12-year-old female pilot whale at San Sebastián. This animal was part of a mass stranding of at least 20 individuals discovered in 1982.

caudal stock could be used to identify individuals at sea, and most adults have a serrated left flipper whose use remains a mystery. One female, at 1.28 meters, was evidently the world's smallest sexually mature cetacean.

Several dolphin species were already known in the area: the pilot whale (18.2 percent of total crania) was represented with at least eight mass strandings of family groups. We found a mass stranding and several individual strandings of killer whales. The Peale's dolphin rarely strands, but is occasionally caught in nets or harpooned. Although it is the species most often sighted around Tierra del Fuego, the cranial specimens represent only 4.7 percent of the total.

The 30 specimens of the pelagic southern right whale dolphin, *Lissodelphis peronii*, almost double the world's collection. None of these specimens were fresh, but they did show that this oceanic species enters channels. As James

Mead once commented, "Maybe they don't realize that the ocean has sides and a bottom."

The dusky dolphin, *Lagenorhynchus obscurus*, was assumed to be common in the area and is present in Beagle Channel kitchen middens (ancient mounds of debris), but we have found only one specimen. The hourglass dolphin, *L. cruciger*, is often sighted offshore and in waters to the south, but we have found only two partial postcranial skeletons. The elusive Chilean dolphin, *Cephalorhynchus eutropia*, has been observed only a few miles away, off southern Isla Navarino, and was present in the middens, but we have found no specimens at all.

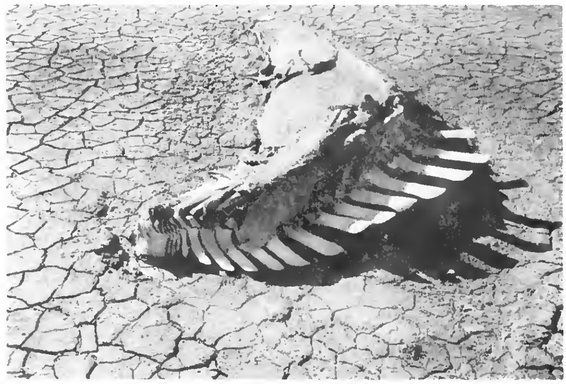
What no one expected to find so far south were Risso's dolphins, most of them in a series of mass strandings of three or four animals; one bottlenose dolphin, *Tursiops truncatus*; and one skull of the false killer whale, *Pseudorca crassidens*, found by staff of the local museum. These latter may represent the equivalent of human vagabonds or polar explorers.

The second-ranking species in frequency, the spectacled porpoise, was formerly considered one of the world's rarest cetaceans. Although we have collected more than 134 crania, only one animal was completely fresh and only two or three others could offer a few details of pigmentation. The sex could be determined for only five males and four females. Although this species has been considered coastal, and a few animals were close enough inshore to be trapped in nets, skulls of the spectacled porpoise have recently been found on offshore islands around the Southern Ocean. It may be more pelagic than supposed; in general, coastal species seldom strand, and this one has stranded often.

The Burmeister's porpoise, *Phocoena spinipinnis*, was known from temperate waters on each side of South America, but was not expected to reach Tierra del Fuego. Nine specimens of varying ages (mostly captures), as well as Beagle Channel sightings of adults and neonates have firmly established its presence.

Perhaps most surprising were the Ziphiidae or beaked whales. Arnoux's beaked whale (*Berardius arnuxii*) and the southern bottlenose whale (*Hyperoodon planifrons*) occur in Antarctic waters and off southern South America, but three species of another genus, *Mesoplodon*, as well as Shepherd's beaked whale (*Tasmacetus shepherdi*) and the Cuvier's beaked whale (*Ziphius cavirostris*), were assumed to be in warmer waters. The most abundant ziphiid was Cuvier's (29.8 percent), followed by the Gray's, *Mesoplodon grayi* (23 percent), and Layard's beaked whales, *M. layardii* (19 percent). Although only a few of the 47 animals were found in fresh condition, a picture of their occurrence is building up. We found adults of only four of the seven species, but neonates, young, and adults of Gray's and Cuvier's beaked whales were present, indicating breeding populations in the area. Two juvenile Hector's beaked whales, *M. hectori*, were found.

The above results pertain to Isla Grande de Tierra del Fuego and Isla de los Estados. We also made several expeditions to the Patagonian province of Santa Cruz and have a few specimens brought to us from the Antarctic Peninsula.



Postcranial skeleton of adult male Layard's beaked whale, Mesoplodon layardii.

Future Research

The analysis of the stranding data may take years. We have started with the most commonly found species and prepared a series of papers on each, on distribution, pigmentation, external morphometrics, food habits, age, reproduction, cranial, and skeletal variation. Two species, Commerson's dolphin and the spectacled porpoise, are represented by enough specimens from neonates to adult animals to permit a detailed study of growth and development within the species.

Having a series of complete skeletons has enabled us to identify cetacean bones found in 6,500-year-old kitchen middens along the Beagle Channel. The slow decomposition rate of animals left on the beach in our Subantarctic climate has permitted an ongoing study of cetacean taphonomy (the break-up and burial of carcasses), which would be impossible in other climates or in areas where cetaceans must be disposed of as a health menace.

We have been hampered by the lack of a veterinarian on our team, but are looking for a specialist to assist in the study of the many bones that are diseased or broken and rehealed. Many projects are being carried out with the cooperation of other cetologists and scientists from other disciplines, for example, in the analysis of stomach contents, parasites, and teeth.

Osteological specimens are being sent to various museums, but the main collection will be kept in Tierra del Fuego. We are hoping to obtain funds to construct a building for specimen storage, research, and display for the public.

Financing such an "opportunistic" type of study has presented some problems for an American living far from universities and foundations. A series of grants from the Committee for Research and Exploration of the National Geographic Society has been the backbone of the program. Support during three and a half

The species of cetaceans found in beach surveys in Tierra del Fuego, Provincia de Santa Cruz, and Antarctic Peninsula

	TIERRA DEL FUEGO			OTHER AREAS		TOTAL
	Cranial specimens	Post-cranial	Total specimens	Cranial specimens	Post-cranial	Number identified
			SMALLER CETACEANS			
Commerson's dolphin	252	83	335	17	8	360
Chilean dolphin	[1]	–	–	–	–	–
Risso's dolphin	19[2]	2	21	2	1	24
Long-finned pilot whale	124[3]	45	169	4	–	173
Peale's dolphin	32	24	56	1	1	58
Hourglass dolphin	–	2	2	–	–	2
Dusky dolphin	1	1	2	–	–	2
Southern right whale dolphin	30	20	50	2	–	52
Killer whale	30[2]	7	37	1	1	39
False killer whale	[4]	–	–	–	–	–
Bottlenose dolphin	1	–	1	–	–	1
TOTAL DELPHINIDS	489	184	673	27	11	711
Spectacled porpoise	134	101	235	2	2	239
Burmeister's porpoise	9	3	12	–	–	12
TOTAL PHOCOENIDS	143	104	247	2	2	251
Arnoux's beaked whale	2	1	3	2	–	5
Southern bottlenose whale	7	6	13	3[2]	–	16
Gray's beaked whale	11	5	16	1	–	17
Hector's beaked whale	2	1	3	–	–	3
Layard's beaked whale	9	1	10	3	1	14
Shepherd's beaked whale	2	2	4	1	–	5
Cuvier's beaked whale	14[2]	8	22	3[2]	1	26
TOTAL ZIPHIIDS	47	24	71	13	2	86
Pygmy right whale	1	–	1	–	–	1
TOTAL SMALLER CETACEANS	680	312	992	42	15	1049
			LARGER CETACEANS			
Sperm whale	50[2]	11	61	–	–	61
Southern right whale	1[2]	2	3	–	–	3
Minke whale	11[2]	2	13	–	–	13
Sei whale	9[2]	–	9	–	–	9
Blue whale	–	–	–	–	–	–
Fin whale	–	–	–	–	–	–
Humpback whale	–	1	1	–	–	1
TOTAL LARGER CETACEANS	71	16	87			87

[1] Specimens have been found in the Beagle Channel middens and sighted nearby, but we have no recent specimens.
[2] Includes some cranial specimens that remain on the beach for which measurements, teeth, baleen, or earbones were taken as vouchers. Mandibles found alone were included under postcranial specimens.
[3] Includes 78 crania and 46 other specimens with teeth, earbones, etc.
[4] One of these specimens is in the collection of the *Museo Fin del Mundo* in Ushuaia.

years came from the *Consejo Nacional de Investigacion Científica y Técnica*, which recently offered me a part-time salary. Smaller grants have come from the *Secretaría de Estado de Ciencia y Technología*, the Connecticut Cetacean Society (now the Cetacean Society International), and private benefactors. The state oil company, YPF, private oil companies in Tierra del Fuego, and the local *estancias* have helped us with fuel, food, equipment, and a place to stay. When all else fails, I rely on the proceeds from the sale of my own maps and books on Tierra del Fuego. Without the enthusiastic help of a long string of part-time employees, students, and volunteers, most of the specimens would still be on the beach.

Though we have patrolled the same beaches many times, about 80 to 90 specimens appear year after year through strandings and incidental captures. With good health, financing, and interested assistants, the program will continue indefinitely. □

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A Rescue That Moved the World

by Mark A. Fraker

For three weeks last October, three gray whales were trapped in the ice near Barrow, Alaska, a small Eskimo settlement about 800 miles north of Anchorage and about 200 miles west of the Prudhoe Bay oilfield. The effort mounted to extricate these animals from their predicament brought together a most eclectic coalition—Eskimo whalers, government agencies, the military, petroleum and other private companies, and Greenpeace—joined in the final phase by the Soviets (Table 1). These groups would work under severe Arctic conditions that were a test for both men and machines. The effort to save these whales was to capture the world's attention for more than two weeks.

On 7 October, Roy Ahmaogak, a local Eskimo, discovered the animals just north of Plover Point, about 10 miles from Barrow. The word spread quickly, first in Alaska, and then across the United States and the world. Soon several of us found ourselves in Barrow. And like the whales, we were trapped there until the situation was resolved one way or another.

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Reporters record trapped gray whale off Barrow, Alaska. (Photo by Jim Harvey, National Marine Mammal Lab)

I first became aware of the whales on 12 October from a newspaper article, five days after the whales had been discovered. The next day BP Exploration Alaska Public Affairs Manager Susan Miller called me and asked what, if anything, could be done to save these animals. Given the severe Arctic conditions, the remote location, and the fact that it was a natural occurrence, I suggested letting nature take its course—nothing practical could be done. However, by Saturday, 15 October, it became apparent that a rescue effort would be mounted, and the President of BP Exploration (Alaska), Inc., George N. Nelson, asked me and Public Affairs Associate Frank Baker to go to Barrow and offer what assistance we could.

Baker and I spent the weekend getting ready. At the same time, in cooperation with Ron Morris, rescue coordinator for the National Marine Fisheries Service, an arm of the National Oceanic and Atmospheric Administration (NOAA), a large effort was being mounted at Prudhoe Bay by ARCO Alaska and Veco, Inc. to mobilize a hoverbarge that had lain idle for several years. This barge had ice-breaking capabilities that could perhaps open a path to the water for the whales to escape. But the barge could be propelled only by a large helicopter, and there were no suitable commercial choppers available in Alaska. Only the National Guard had a sufficiently powerful craft, a CH-54 Sky-Crane.

An appeal was made to Alaska Senator Ted Stevens, who in turn contacted the Pentagon. It was quickly decided that the whale rescue would be a suitable training exercise for the National Guard, and soon two Sky-Cranes were on their way to Prudhoe Bay, while a UH-1N Huey helicopter was dispatched to Barrow to provide logistics support.

Table 1. List of organizations cooperating in the rescue of the gray whales near Barrow, Alaska.

National Oceanic and Atmospheric Administration
- National Marine Fisheries Service
- National Weather Service
- National Ocean Service

North Slope Borough
- Department of Wildlife Management
- Search and Rescue
- Planning Department

Barrow Whaling Captains Association

Department of Defense
- Alaska National Guard
- U.S. Air Force

Department of State

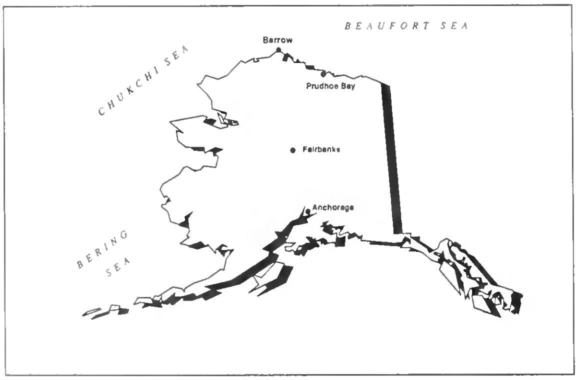
Department of Transportation
- U.S. Coast Guard

Petroleum Industry
- ARCO Alaska
- BP Exploration Alaska, Inc.
- Veco, Inc.

Other Industries
- Omark Industries (Oregon Chainsaws)
- Kasco Marine (de-icers)
- Alaska Airlines
- Mark Air

Greenpeace

The Government of the USSR.



Sudden icing caught the whales near Barrow, Alaska.

The objects of this rescue were three young gray whales, ranging from about 25 to 35 feet long, and from nine months to two-and-a-half or three-and-a-half years in age (Table 2). They probably had been feeding in the area near Plover Point, and as temperatures dropped and ice formed all around them, they became confined to just two openings.

The whales were trapped within an absolutely stable sheet of land-fast ice (Figure 1). It was protected on the east by a shoal area with grounded old ice anchoring it, and on the west by a heavy grounded ice ridge, a quarter- to a half-mile wide, through which the whales would have to pass to gain access to open water. No amount of wind would have been able to move that ice. Only some sort of human effort could create the open water needed by the whales to swim to freedom.

Although it was only ice that separated the whales from the open lead, the heavy, grounded, ridged ice, some of it extending 50 feet into the air and 30 feet to the sea floor, presented a vastly different problem from that presented by the smooth, stable, floating land-fast ice.

Comfortable as Possible

Baker and I arrived on 17 October with our chainsaws, and we began to work with Tom Albert, Craig George, Geoff Carroll, and Billy Adams from the Department of Wildlife Management of the North Slope Borough, the local governing body, to enlarge the holes and keep them open. Our intent was to make the whales as comfortable as possible until the hoverbarge arrived to create a path for the animals.

We found it remarkable that the whales moved readily between the two openings, even in darkness. How they navigated over the approximately 100-yard distance is unclear. Maybe they simply memorized the spatial relationship, or perhaps they somehow used underwater sound to help them find their way.

On Tuesday, 18 October, we worked to enlarge hole number 1 and also created two new holes near the two that the whales had been using, to see if the whales would readily move

The three gray whales in hole number 1. Billy Adams holds a chainsaw used to keep ice open. (Courtesy of Frank Baker)

into them (Figure 2). But even though the new holes were only about 40 to 60 paces from hole number 1, neither was used by the whales, which by now had been given the names "Bone," "Bonnet," and "Cross." This caused us to become concerned about whether the whales would readily move from the two holes to which they had become so accustomed.

Wednesday, 19 October, was spent enlarging hole number 2. Baker and I were the last people off the ice that day, and we were concerned. The temperature had dropped and blowing snow was causing ice to accumulate in the holes faster than we could shovel it out. Clearly, something would have to be done to keep the holes from freezing over.

We sounded the alarm when we returned to the Barrow Search and Rescue Center. And as luck would have it, Rick Skluzacek and Greg Ferrian from Kasco Marine in Lakeland, Minnesota, had arrived that afternoon with de-icing machines that they said would keep the holes open. They had phoned earlier in the week to offer the machines, but were politely refused. Yet they came up on their own, and they and their machines proved to be essential to the effort. People rushed to locate generators and extension cords and prepare them for use. That night they were transported out to the site by helicopter, and about midnight, the first de-icers were deployed.

The de-icers are simply electric motors with a propeller enclosed by a protective wire cage. They work on the simple principle that seawater contains enough heat to keep it from freezing. If the surface water can be replaced with warmer water before it freezes, a hole can be kept open.

There was another interesting observation made on that bitterly cold night. The first de-icer was deployed in hole number 1, the hole that the whales had been using. Not only did the whales continue to use hole number 1, but they seemed to show an interest in the de-icer itself. Suspicions that the whales found the de-icers attractive were raised further when the second de-icer was placed in hole number 2 and within minutes the whales entered hole number 2.

On the morning of 20 October, we discussed a simple experiment. The experiment was inspired by the whales' apparent interest in the de-icers the night before, and the fact that gray whales in Baja California lagoons are often attracted to the sounds of outboard motors.

We created two new openings, holes number 5 and 6 (Figure 3), with 5 adjacent to opening 3. Hole number 3 had been created two days earlier, but had since refrozen. After the de-icers had been started up in holes 5 and 6, we shut down the de-icers in holes 1 and 2. Within 15 minutes the whales entered hole number 5,

Table 2. Estimated size and age of the three gray whales trapped in the ice near Barrow, Alaska.

	Length in feet	Weight in pounds	Age
"Bone"	25	10,000	9 months
"Bonnet"	27 – 29	14,000	9 – 21 months
"Cross"	33 – 35	20,000	2.5 – 3.5 years

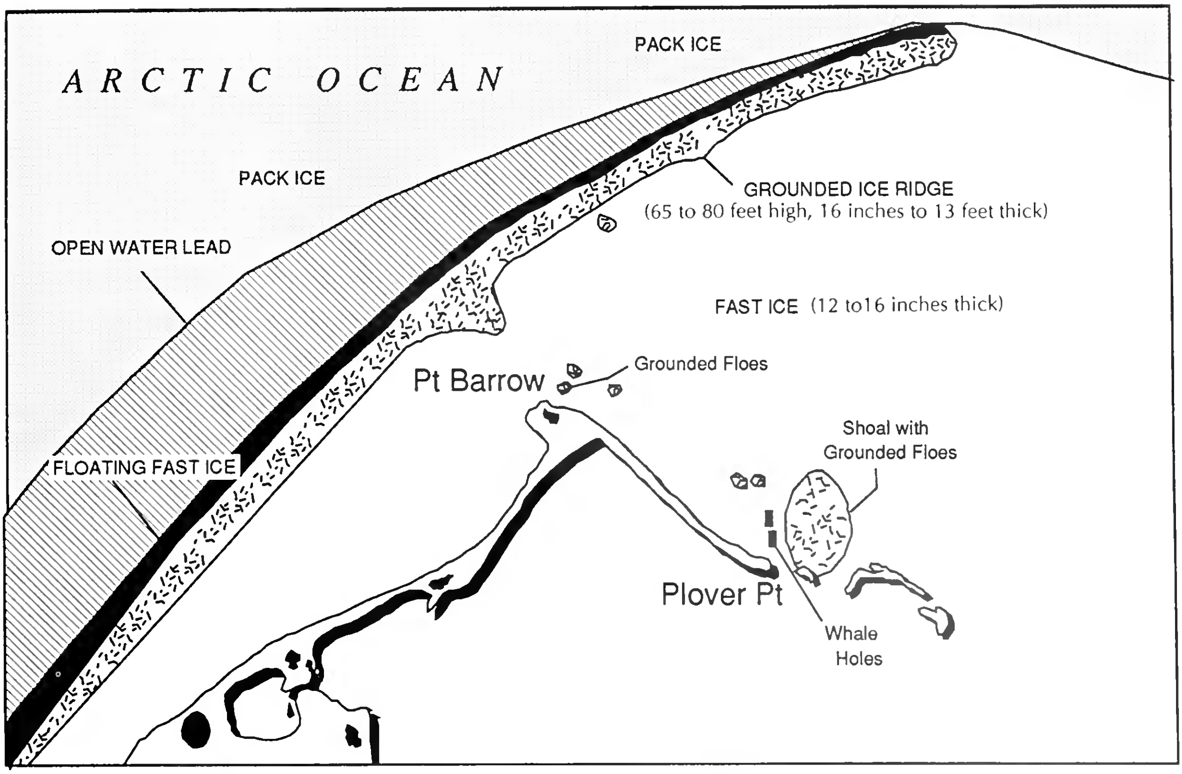


Figure 1. The frozen-up area in which the whales were trapped. The grounded ice ridge formed an imposing barrier.

went through a normal series of respirations, but then returned to hole number 1. However, we later found out from Geoff Carroll and Craig George, who had stayed out on the ice that night, that the whales had occasionally explored the two new openings. We found this information somewhat encouraging: perhaps the whales could be induced to use a path created through the ice for them, motivated to move by the sounds of the de-icer machines.

By Friday, 21 October, two weeks had elapsed since the whales were first discovered, and about one week had gone by since the rescue effort began. It was apparent by then that the hoverbarge had been stopped cold by the densely packed grounded floes near Prudhoe Bay.

Armed with a number of recently arrived Oregon chainsaws, the Eskimo whalers under the leadership of Arnold Brower, Jr., a prominent Eskimo whaler himself and a descendant of a Yankee whaler who settled in Alaska in the 19th century, took the initiative and began to create a series of openings leading toward a narrow part of the ice ridge, which lay about five miles to the north. The basic process was to cut a series of rectangular slabs of ice with chainsaws, and for a group of men on one side to force one end of the slab under water while a group on the other side used poles to push the slabs under the ice sheet. In this way, an opening about six to eight feet wide and 30 feet long could be created in about 15 minutes.

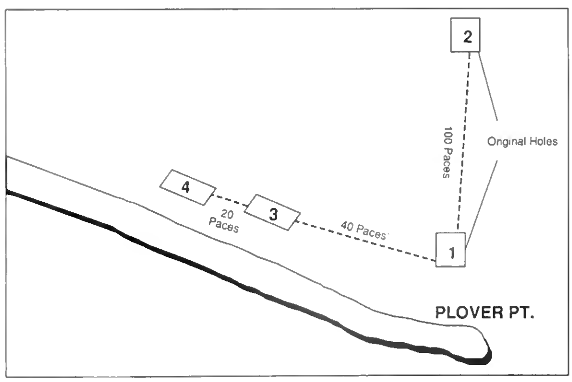


Figure 2. Original holes (1 and 2) and new ones (3 and 4)

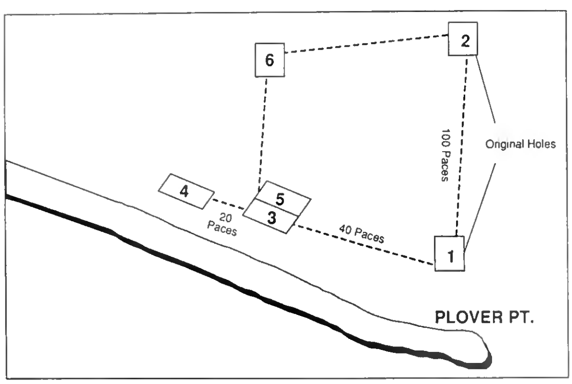


Figure 3. After new holes were cut, holes 3 and 4 refroze.

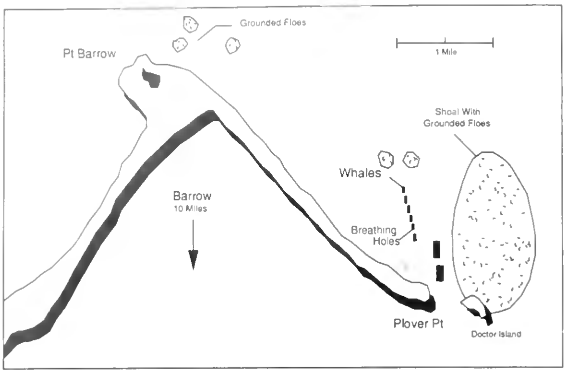


Figure 4. Location of whales and holes by 21 October.

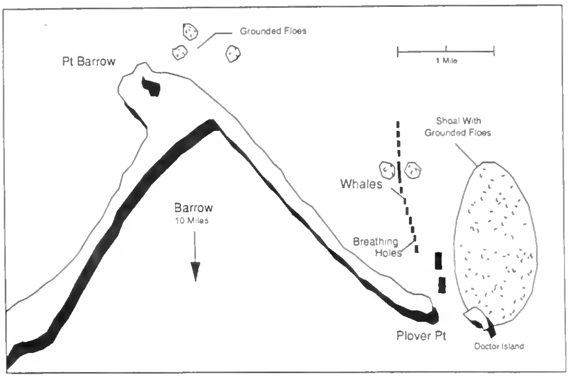


Figure 5. By 23 October, more holes had been added.

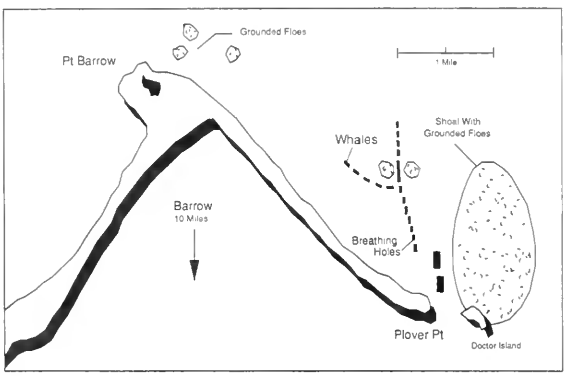


Figure 6. By 25 October, a new channel was opened.

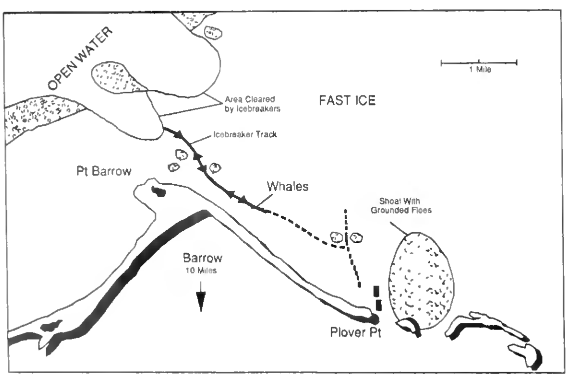


Figure 7. By October 26, the icebreakers were at work.

By 6 P.M. the Eskimos had completed a series of openings stretching about one-third of a mile (Figure 4), some of which were equipped with de-icers. Nearly everyone came off the ice at that time to warm up in a heated trailer that had been dragged to Plover Point. As two of us were standing outside the trailer, we noticed whale "heads" moving along the ice. The whales were using the openings, and many of us ran out onto the ice to celebrate the moment.

There was a sad note, however. "Bone," the smallest whale, was missing. I suspect that "Bone" became disoriented when the others made the move to the new holes, and drowned.

If a large number of openings were to be created, allowing the whales to negotiate four to five miles through the ice, it was apparent that more support equipment would be needed. There would be a shortage of poles suitable for pushing ice. Additional generators would be required to power the de-icers, and floodlights would be needed to aid the workers on the ice during darkness (which at that time of year lasts about 16 hours a day). A mechanic would also be needed to help keep the generators and chainsaws operating in subzero temperatures out on the sea ice. After a quick call to BP Exploration's base at Prudhoe Bay, poles were fabricated, equipment rounded up, and Rod Wirshing and Gene Barnhart arrived to keep the engines running and to expedite equipment from Prudhoe Bay as needs were recognized.

On Saturday and Sunday, 23 and 24 October, the Eskimos continued to cut openings, but the whales would move only so far (Figure 5). All of us were puzzled and discouraged. Why would the whales go no further? The water was about 12 feet deep here, and that seemed adequate, especially when more ice was removed to create a long uninterrupted opening over the shoal.

Help from the Soviets

Meanwhile we had good news. Through the efforts of NOAA, Greenpeace, and the State Department, the government of the USSR agreed to dispatch two icebreakers that would attempt to break through the barrier created by the grounded ice ridge. (Neither of the two Coast Guard icebreakers was close enough to be of help in time.) Also, an easterly wind was forecast, and this would help carry the broken ice seaward.

Ice scientists Gary Hufford (NOAA) and Robert Lewellen (BP Exploration), working with Eskimo elders, assessed the ice conditions. Using power augers, they drilled through the ice, and with a weighted line made depth soundings to help guide the Soviet vessels in the very shallow water in which they would have to operate to get close to the whales.

The news of the icebreakers also changed the objective for the Eskimo crews. No longer would they have to aim for a narrow point in the ice ridge; the icebreakers would be able to carve out a huge opening, not just a narrow channel.

This meant the whales could be led along a more direct route, parallel with the spit (Figure 6).

Now the Eskimos created openings in the somewhat deeper water that lay landward of the shoal area, and the whales followed right along (Figure 7). It suddenly became clear to us that the whales had been reluctant to move because of the shallow water. Brower spoke for all of us when he said: "We just didn't have the mentality to understand what the whales were trying to tell us."

Eskimo crews push freshly cut slabs of ice under the adjacent ice to create an opening. Note the Soviet icebreaker in distance. (Courtesy of Frank Baker)

On Tuesday, 25 October, the crews worked to make new openings. At the same time, the Soviet icebreakers were making mincemeat of about three square miles of the huge ice ridge that had threatened the success of our effort.

The hole-making continued on Wednesday, 26 October, and it was the hope of everyone that the whales would gain their freedom that day.

I don't normally become emotional about whales, nor do I usually impute emotion to the behavior of animals. However, all of us out on the ice that day could feel a contagious energy, from both people and whales. The whales were entering the new holes even before the chainsaws had finished all the cutting. They seemed more vigorous and energetic. We all felt that the whales sensed that they were being led in the right direction, and that they were eager to get out to open water.

A Trail of Rubble

To our surprise, the smaller icebreaker *Arseniev* had made a run into very shallow water (Figure 8). But unlike the rest of the work that the icebreakers had done, this run created only a trail of rubble with little open water, and this had largely refrozen.

Late in the afternoon *Arseniev* made another run toward the whales along its first track, and the whales entered it. However, as night fell, we had to leave, and it was apparent that the whales were finding the icebreaker's track rough going.

Eskimos were on the scene before light on Thursday, 27 October, and the whales were confined to a small opening in the ice. They had obviously had a difficult night, suffering several new cuts and abrasions. Fortunately the new wounds appeared to be superficial, and the whales had traveled about a mile and a half in the right direction. (Unlike "Humphrey," the humpback whale that had become lost in the Sacramento River in California a few years earlier, these whales seemed to know the direction to travel.)

The Eskimos now proceeded toward an area where the whales could be released into open water. As they proceeded, however, *Arseniev* inexplicably crossed the intended path (Figure 9). This created a problem because it was impossible for people to move safely across broken ice in the icebreaker's track, and the ice-edge objective could not be reached that day.

Time had always been critical in this project, and in many respects we had had more than our fair share of good fortune. But now, more than ever before, time was of the essence. The weather was severe enough by most people's standards, but it would get worse. The Soviet icebreakers had been on a very long cruise, and they were eager to return home.

The decision was made to leave the whales at the last hole with a de-icer and a floodlight. The floodlight would guide the icebreaker, which would approach to within about 50 feet of the hole that night.

At one point, the icebreaker reported seeing one of the whales enter its track. However, early the next morning, the whales were found in the last opening that had been created for them by the Eskimos. At 8:45 A.M., an Eskimo on the scene reported that the whales had made a final move down the new track.

Morris, Cindy Lowry (Greenpeace), and others flew out by helicopter to the location to verify the situation that morning, and they found evidence that the whales had indeed made good their escape. At the same time, I and some others flew for about 15 miles along the open lead, and although we did not see the whales, we did see an enormous amount of open water that they could swim in.

What were the results of all this effort? First, there surely was a large increase in public

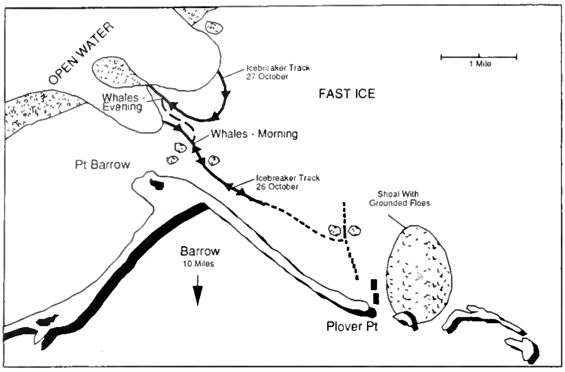


Figure 8. By 27 October, icebreakers cut two tracks.

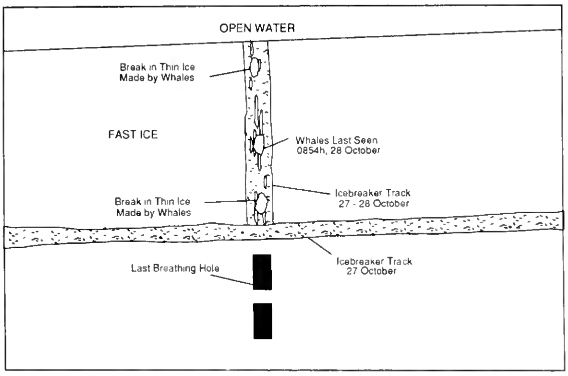


Figure 9. On 28 October, the whales made their break.

awareness about gray whales in particular and probably whales in general. The whale rescue had been a major news story on television and in the newspapers for two weeks, not only in the United States but around the world.

Second, it put Eskimo whalers in a new light. Some people think that the Eskimos are interested only in killing whales, but news coverage showing them working to create openings for the whales' escape must have changed some opinions.

Third, it was a valuable exercise that suddenly brought together people from diverse organizations and with diverse expertise. We were all faced with trying to solve problems that we had never faced before, under hostile conditions. This event was filled with firsts.

Fourth, I think we can all rejoice whenever there is international cooperation, particularly with the Soviets. I have always enjoyed the contact that I have had with Soviet scientists and can't help but feel that each positive contact improves mutual understanding and goodwill.

Certainly, this event created much more excitement and attention than one could have reasonably asked of three gray whales. As Brower said, "Nothing like this will ever happen again in our lifetimes. And probably not in the lifetimes of our children, or our children's children." □

Eskimo crews created a chain of breathing holes through which the whales could travel. (Courtesy of Frank Baker)

Let's Have Less Public Relations And More Ecology

by Peter L. Tyack

The heroic and expensive efforts to free three California gray whales, *Eschrichtius robustus*, from the ice off Point Barrow last fall evoked a powerful response among many Americans. Hundreds of reporters and photographers flocked to Alaska, and the sounds of the whales struggling to breathe were carried by television into millions of living rooms. Freeing the whales was a "feel good" action and a public relations coup for environmental organizations that have spent millions of dollars to make killing whales appear immoral. However, even the most sympathetic viewers had to wonder how and why federal agencies decided to collaborate in so costly an enterprise that managed to save, perhaps only temporarily, only two trapped whales (of a population of 20,000).

In part, the answer lies in the special status that whales have acquired as a symbol of our interest in the environment. Like the sacred cows of India, they have come to require official protection. Yet it's one thing for a privately funded organization like Greenpeace to stage an environmental "action" on their behalf, and quite another for the government to do so. Indeed, its participation was exquisitely rich in ironies. How could it undertake heroic measures for whales of a species that has mostly recovered, while allowing Eskimos to kill more endangered bowheads, *Balaena mysticetus*, in the very same area?* And didn't the commitment of precious resources for the rescue mean that it was in effect choosing not to devote them to more pressing problems facing endangered whales?

Regulations and Regulators

The agency on whose shoulders these questions fall is National Marine Fisheries Service, an arm of the National Oceanic and Atmospheric Administration (NOAA). Under the Marine

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Freeing the grays made us "feel good" but was it sensible? (Courtesy of National Marine Mammal Lab)

Mammal Protection Act (MMPA) of 1972, it has the responsibility for protecting whales, dolphins, and seals. But in carrying out that Congressional mandate, it has displayed striking inconsistencies, of which the questionable rescue of the trapped grays is only one conspicious example. Time and again, NOAA Fisheries has acted politically rather than ecologically. It is more likely to target problems that yield a quick

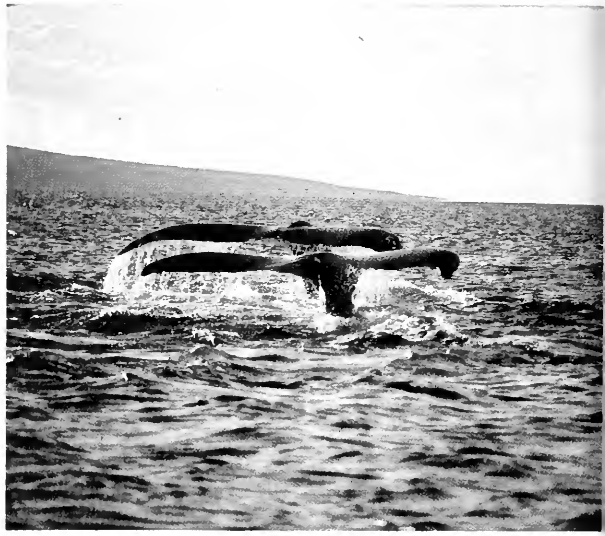
*Aboriginal whaling of bowheads has long been an issue for U.S. policymakers. In 1977 the International Whaling Commission (IWC) became so concerned about this species, one of the most endangered, that it banned all whaling of bowheads. The United States had to decide whether Alaskan Eskimos should be allowed to continue their aboriginal whaling. In the ensuing conflict between whale conservation and native rights, the latter won. The United States persuaded the IWC to grant the Eskimos an annual quota for hunting bowheads—35 whales in 1988—in spite of their endangered status. Thereupon other nations requested aboriginal hunts of the less-endangered gray and humpback whales.

payoff in public relations rather than those that pose the greatest threat to marine mammals.

Passed after a decade of growing environmentalism, the MMPA was the government's response to this increasingly powerful movement, which looked with alarm not only on commercial whaling, but also on the incidental kill of hundreds of thousands of dolphins each year by the U.S. tuna purse-seine fishery in the Pacific. The act committed the United States to long-term management and research programs to protect marine mammals. It also prohibited Americans from either importing or "taking" the animals—the latter a euphemism for killing, harassing, or removing them from the wild. But while marine mammals are the focus of the act, it had a broader goal—"the primary objective of their management should be to maintain the health and stability of the marine ecosystem" (Section 2.6, MMPA). As Patricia Birnie pointed out, the MMPA is "distinguished as the world's first legislation recognizing that maintenance of habitats is a prerequisite of survival of a species, and is aimed at international as well as national protection."

In 1973, the Endangered Species Act (ESA) was enacted and joined the MMPA as the principal means employed by the United States to protect endangered marine mammals. The ESA's defined purpose was "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved" (Section 2b, ESA). It mandated that federal agencies formulate recovery plans for endangered species and establish management priorities for their protection, especially those threatened by the long-term effects of economic development. It also specified that areas crucial for the survival and reproduction of endangered species may be designated *critical habitats*, subject to special protective regulation. For all its powers, however, NOAA Fisheries has not declared critical habitats for any marine mammal species, nor has it implemented any broad policies to protect marine ecosystems.

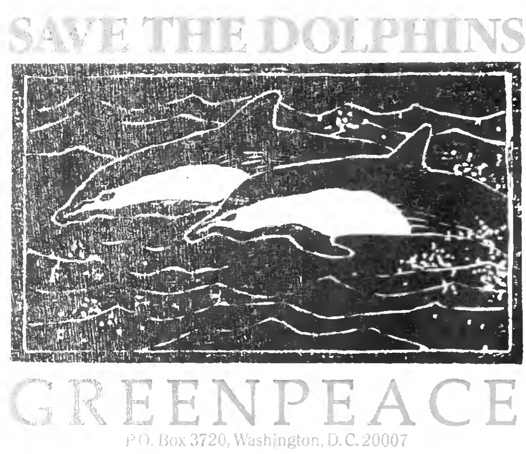
Great whales, all of which have been declared endangered under ESA, have been objects of particular concern. Many feed, breed, or migrate in U.S. coastal waters, where they encounter heavy shipping traffic, intensive fishing, and such byproducts of coastal development as pollution. In spite of the threat to their habitat, however, not a single recovery plan has been formulated since the legislation's passage. Only in the past year, after considerable pressure, is NOAA Fisheries finally beginning work on recovery plans for two of the most endangered species, namely humpback whales, *Megaptera novaeangliae*, and right whales, *Eubalaena glacialis*.



Recovery plans are finally being drawn for species like these humpbacks. (Photo by Jordan Coonrad)

There are still more obvious inconsistencies in NOAA Fisheries policy. If the Federal government supports heroic measures to save three gray whales, why has it granted exemptions from the law that let American and foreign fishing fleets incidentally kill tens of thousands of marine mammals each year?

Admittedly NOAA Fisheries faces tough political choices. Special interest groups, such as the Eskimos or the tuna fishery, are formidable adversaries. They've been able to hire good lawyers and get around the clear intent of the law. For example, an "immediate goal" of the MMPA was "that the incidental kill or serious injury of marine mammals permitted in the course of commercial fishing operations be reduced to insignificant levels approaching a zero mortality and serious injury rate." Quotas limiting the number of dolphins killed by tuna fishing did in fact reduce dolphin mortality from around 368,000 in 1972 to 20,000 or so in 1978. But there has been no improvement since then. Between 10,000 and 20,000 dolphins are still dying in tuna nets each year, largely because NOAA Fisheries has



The death of dolphins in fisheries is a matter of concern.

consistently backed away from the law's zero mortality goal in face of the tuna fishing industry's effective lobbying.

Instead of selecting targets for regulation based on their potential impact on whale populations, NOAA Fisheries has taken the easier course, choosing those that are highly visible and less likely to resist. One of its targets has been research, even though both the MMPA and ESA contain specific provisions allowing animals to be taken for scientific purposes and public display on the grounds that these activities are likely to benefit endangered marine mammals.

By 1975 more than 100 permits had been granted to individual researchers as well as aquariums and oceanariums for marine mammals. Indeed, the Marine Mammal Commission was so concerned by bureaucratic delays that it urged NOAA Fisheries to establish a two-tier permit system: it would reduce regulatory demands on research activities with no determinable adverse impact, such as census and behavioral studies, while maintaining strict control on research that required killing animals.

NOAA Fisheries ignored this recommendation. Instead, it got tough with researchers, who were less likely to resist than the tuna fishing industry. When scientists inquired whether they needed permits for activities they considered harmless, such as carefully approaching whales in small boats, NOAA Fisheries regulators made it clear that they wanted all research activities brought under their control. This allowed them to claim that they were regulating even activities that posed only a remote risk of being harmful to whales.

Research at Risk

The singling-out of scientists for regulation has led to paradoxical situations. If I want to study the effects of ship noise on whales, for instance, I must file for a permit, while none is required of the hundreds of large ships that regularly plow past concentrations of the endangered animals in which I'm likely to do my work. These not only may disturb the whales with their loud noises but occasionally strike them as well, inflicting injury and sometimes death. Recently, NOAA Fisheries expanded its regulatory net still further by requesting permits for active acoustic research such as geophysical surveys and ocean acoustic tomography sources, though there's little probability that such work will injure a whale.

On the other hand, the regulators avert their eyes in the case of activities likely to kill marine mammals outright, such as the California gill- and trammel-net fisheries, that are responsible for the deaths of some 200 to 300 harbor porpoises, *Phocoena phocoena*, annually (article, pp. 63–70). NOAA Fisheries doesn't require the fishermen to obtain permits for their "takes," nor has it prosecuted them for killing porpoises. And the few fisheries that must obtain permits for the mammals they kill, such as the Japanese salmon gillnet fishery, which is responsible for the deaths of thousands of Dall's porpoises, *Phocoenoides dalli*, each year, operate under blanket permits issued to fishing consortia. These permits impose much less of a burden on individual fishermen than those required of research groups.

The discriminatory policy against researchers reverses the original intent of the research permits, which was to allow scientific activities that would otherwise be prohibited.

Aiming for the Easy Targets

NOAA Fisheries' latest target is whale watching, which has enjoyed a spectacular growth on both coasts and in Hawaii in the last decade (article, pp. 84–88). Both the MMPA and ESA prohibit "taking" whales by harassment. The original intent was to protect marine mammal populations from human activities that might not cause immediate mortality but were harmful to the animals in the long run. There's no evidence that whale watching, if it's conducted responsibly, harms individual whales, much less whale populations. Nonetheless, NOAA Fisheries has broadened the definition of harassment to include any disturbance of the animals' normal behavior. The purpose is to bring approaches by small vessels carrying whale watchers under the law.

Whale watching has become the latest target of government regulation. (Photo by Flip Nicklin)

Why pick on whale watching? After all, it's one of the few human activities likely to benefit whales, since it creates so many advocates for whale conservation. For one thing, like research, it's an easy target, conducted in full public view. For another, the activity is increasing. Hundreds of thousands of people are now going out on whale watches each year, creating understandable concerns about the effects on the whales of all this human curiosity.

When a few reckless whale watchers disturb whales, the public is upset and the industry is alarmed by the adverse publicity, even if there's no long-term impact from the incident on

whale populations. Acting in their own interest as well as the whales', whale watching organizations have begun to work with NOAA Fisheries to develop formal regulations governing their industry.

But there are pitfalls in enforcing regulations when there is no demonstrated impact upon populations. An example is a NOAA Fisheries effort to limit approaches by boats in the Hawaiian Islands. More than a decade ago, NOAA Fisheries published a notice of interpretation suggesting no approaches closer than 300 yards in calving grounds, and 100 yards elsewhere in the islands. Since then, NOAA Fisheries has administered studies of the effects of boats on humpbacks in Hawaii and Alaska. Both showed that whales avoided boats at ranges of one to several kilometers, 10 to 20 times the range suggested before there were any data.

The studies raise serious questions about the strategy of singling out for regulation boats that intentionally approach whales. The average spacing of humpbacks on the Hawaiian breeding ground is less than one kilometer, so any boat transiting it is likely to evoke responses from whales. More important than close approaches is the cumulative impact of the total boat traffic on the breeding ground.

Why then did NOAA Fisheries prefer 100 yards over 300 yards when it proposed new regulations in 1987? In its discussions of the proposed regulations, it gave a hint: it acknowledged that neither limit was adequate as a safeguard against harassment, but then it went on to say that a 300-yard limit "could adversely affect whale watching tour operators," that is, they wouldn't be able to bring customers close enough to see the whales. Is it appropriate for the agency to devote scarce management resources to helping industry rather than helping endangered whales?

Subtle Effects of Human Activities

The public relations successes of NOAA Fisheries obscure even deeper failures. The agency has yet to complete recovery plans for any of the endangered great whale species. It states that it has resisted developing these plans in part because of "its uncertainty as to whether or how recovery plans would enhance the protection of the species." And there are some grounds for this claim. Most populations of endangered great whales seem to be doing pretty well. The ESA was developed with terrestrial species in mind, and it's relatively simple to see the direct conflict between construction and other economic activity on critical habitats for endangered terrestrial species. But the effects of human activities on marine animals are often more subtle. How can one even choose which species are most threatened, or which activities are most threatening, without careful research on the long-term cumulative consequences of development? This kind of research and monitoring is expensive, but it is necessary for developing any rational management and regulatory priorities.

The fin whale is one of the most elegant of the great whales, but is increasingly at risk from growing boat traffic. (Photo by Karen E. Moore)

If NOAA Fisheries were devoting most of its resources to monitoring the health of marine mammal populations and evaluating the long-term effects of human activities on them, then its resistance to recovery plans could be taken at face value. However, NOAA Fisheries is regulating research and whale watching in spite of the great uncertainty about whether these regulations will actually enhance species protection. It's almost as if NOAA Fisheries is afraid that the recovery plan process will force priorities for managing endangered marine mammals based upon biological need rather than on political expediency.

A switch of regulatory focus from protecting whale populations to protecting individual whales from even minor behavioral disturbance would only make sense after whale populations faced no more direct dangers from human activities. Consider the northern right whale. Of the several hundred individuals identified off the East Coast, some 58 percent bear scars from fishing gear, while eight percent have visible injuries from collision with vessels. Over half the adult mortality since 1970 appears to have been caused by net entanglement and collisions. Yet NOAA Fisheries has done virtually nothing to monitor or reduce the collision hazard.

And even while the public applauds the saving of gray whales trapped in the ice off Point Barrow, we pay almost no attention to the growing dangers these animals face at the other end of their annual migration route. In Laguna Guerrero Negro, one of the breeding and birthing lagoons of this species in Baja California, a direct conflict exists between conservation and economic development. From 1957 to 1967, the lagoon's channel was continuously dredged to accommodate the barges that were carrying out shipments from the largest open salt mine in the world. The number of mothers and calves decreased sharply, and none was sighted again until long after the dredging ceased. Gray whales

prefer calm protected lagoons for giving birth, not centers of hectic industrial activity that also create pollution. Reduction of the number of undisturbed lagoons available for calving and breeding could have a serious impact upon the reproduction of this species. Even for a healthy population like the grays, critical breeding habitats must be protected. In 1971, Mexico declared Scammon's Lagoon, a breeding lagoon for gray whales, a refuge zone, and it limits the entry of vessels under a permit system.

Humpback whales do not have the benefit of habitat protection on their Hawaiian breeding grounds. In fact, the emphasis NOAA Fisheries places on regulating intentional acts of harassment obscures the importance of examining the cumulative effects of all human activities upon whale populations. For example, the California wife-husband research team of Deborah Glockner-Ferrari and Mark Ferrari studied humpback mothers and calves off Maui for more than a decade. Maui has been undergoing rapid coastal development during the last decade, accompanied by an explosion of boating activity, including the introduction of such high-speed aquatic playthings as jet skis. Female humpbacks with their young used to congregate in the sheltered waters near the leeward coast of Maui. Since 1980, though, increasing numbers of mother-calf pairs have been sighted at increasing distances offshore.

Glockner-Ferrari and Ferrari suggest that this movement offshore is more likely linked to the increase in the total number of boats than to any individual acts of harassment. Whales may avoid areas filled with hundreds of boats, but ignore a single boat. This suggests that some boating activities in small doses may be completely compatible with marine mammals, although they become harmful when the numbers increase.

That harm can be more than "psychological" to the whales. In 1987 Glockner-Ferrari and Ferrari, joined by Daniel McSweeney, documented an increase in the number of abnormal, injured, and stranded whales off Maui. Two of the three injured whales in their small sampling had been struck by boats. Other whales had abnormal skin or eye conditions. The authors suggest that these problems may be related to the degradation of the shallow water habitat that has accompanied increased vessel traffic, agricultural runoff, and other forms of marine pollution.

The current NOAA Fisheries strategy of regulating intentional approaches of individual boats is incapable of dealing with these habitat degradation problems. The focus on intentional harassment is unlikely even to help with the vessel collision problem. Few boats intentionally strike whales; it's more likely that the boats striking whales were moving too rapidly to avoid whales that had surfaced in front of them.

NOAA Fisheries lags far behind our neighbors in protecting whale breeding grounds. Mexico led the way by creating refuges for breeding and calving gray whales. The Dominican Republic has declared Silver Bank, the main breeding ground for North Atlantic humpback whales, as a marine sanctuary as well. The Hawaiian Islands contain the main breeding grounds for North Pacific humpbacks. Yet, NOAA Fisheries failed to establish a marine sanctuary there (*Oceanus*, Vol. 31, No. 1, pp. 59–65). It failed to limit human impact on this habitat, and its narrow harassment regulations fail to prevent the abandonment of previously preferred inshore waters by mothers and their young, according to Glockner-Ferrari. These failures contradict the spirit, if not the letter, of the ESA, which specifies that priority for recovery plans should be given to endangered species, such as the Hawaiian humpbacks, whose critical habitats are threatened by development.

But the great whales, migrating throughout the oceans, are less threatened by habitat degra-

Habitat destruction may be the greatest threat to whales like this Hawaiian humpback. (Photo by the author)

dation than many smaller species that may spend their entire lives within a small stretch of river or coastline. In the St. Lawrence River, for example, the resident population of beluga whales, *Delphinapterus leucas*, has been declining for years, even after hunting was prohibited, apparently because of pollution, some of which originates in the United States. These animals are endemic and can't simply leave for a less spoiled environment. Hence, specifying their habitats as critical would be far simpler and much more effective than attempting to provide similar protection for more wide-ranging whales.

NOAA Fisheries has scarcely begun to address the issue of habitat protection for marine mammals. One blatant example of habitat degradation for marine mammals is lost fishing gear. Drifting fishing nets kill uncounted numbers of cetaceans, pinnipeds, and sirenians each year. Significant mortality may also stem from such marine debris as plastics (*Oceanus*, Vol. 31, No. 3, pp. 29–36). Federal agencies have held workshops and conferences on these problems, but they have been less inclined to regulate this situation than whale watching.

During the summer and fall of 1987, hundreds of bottlenose dolphins, *Tursiops truncatus*, washed up dead along the mid-Atlantic coast. Post-mortems revealed signs of infection by disease-causing organisms, and high levels of chlorinated hydrocarbons and toxins of biological origin. Were these two findings somehow connected? Some scientists speculate that the

animals may have been suffering from impaired immune function due to marine pollution. This would have increased their susceptibility to disease (box, page 79).

Organochlorines and heavy metals accumulate in all cetacean species tested so far, even in fetuses. The implications of this contamination for the health of these animals isn't clear yet, but it has been suggested that the die-off of seals in the North Sea during the summer of 1988, like those of the belugas and bottlenose dolphins, may be linked with marine pollution. There are even indications of cetacean responses to pollutants in the absence of obvious increases in mortality or decreases in fertility. Studying tissue from minke whales, *Balaenoptera acutorostrata*, caught by Norwegian whalers, Anders Goksøyr of the University of Bergen and coworkers last year found elevated levels of organochlorines. All these whales appeared healthy, but some had levels of toxic compounds sufficient to activate an enzyme system that detoxifies foreign compounds within their bodies. We now need to determine if and how such toxic compounds affect the fertility and mortality of these animals.

Overseeing Complex Interrelationships

Habitat protection involves more than monitoring toxin levels, however. It requires overseeing many interrelationships within a complex ecosystem. For example, marine mammals and humans compete for some of the same fish resources. Killer whales, dolphins, seals, and sea lions off our Pacific Coast regularly snatch fish from fishing operations. The government response has been to consider easing the strict protections required by the MMPA and to look for ways of protecting the fisheries.

Less attention has been given to the question of whether human fisheries are reducing the available prey of endangered species to such an extent as to affect their recovery. Rough calculations of consumption by cetaceans indicate that in many areas they consume about the same biomass as human fisheries. The existence of such a balance points to a possible way of setting limits for fisheries and cetaceans. However, these relationships are unpredictable. While fishermen in many parts of the world have killed marine mammals because they view them as competitors, there are no clear data on the extent of the competition.

Canadian biologists have recently suggested that culling the population of gray seals off the Maritime provinces may improve Canadian fishery catches. Will agencies responsible for facilitating the recovery of marine mammal populations be equally keen on suggesting limits on human fisheries in order to foster the recovery of depleted marine mammal populations?

Clearly, the competition between marine mammals and human fisheries may lead to important and unpredictable consequences. For example, there's a suggestion that young herring, which were overfished on Georges Bank during the 1960s and early 1970s, were driven nearly to local extinction by continued predation from fin whales, *Balaenoptera physalus*. When NOAA Fisheries sets its quotas for commercial fishing, it hasn't taken this kind of effect into account. But as marine mammal populations continue to grow, these effects are likely to become even more important. One responsibility of NOAA Fisheries is to determine whether fisheries are limiting the recovery of endangered whale populations. The entire question of multispecies, or ecosystem, management and the effects of competition between human fisheries and marine mammals on prey populations requires careful study to enable rational management of both.

The next few years will offer an excellent opportunity for NOAA Fisheries to abandon its tendency to regulate what's easy instead of what's important. Under prodding from the Marine Mammal Commission, NOAA Fisheries has committed itself to developing recovery plans for the most endangered whales. If NOAA Fisheries can develop biologically relevant management priorities for these species, it may be able to allocate its limited regulatory and enforcement resources more effectively. It's particularly important for NOAA Fisheries to investigate the unintended long-term consequences of a broad range of human activities, and to take an ecosystem-level approach to habitat protection rather than focusing on narrow harassment regulations. This might reverse the current situation in which research, rather than being facilitated by government policy, is discouraged by excessive regulation. Such a new policy would do more for the preservation of endangered species than policies based upon politics and PR. □

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The majesty of this breaching right whale belies the threatened condition of the species. (Photo by David Wiley)

How Much Is a Whale's Life Worth, Anyway?

As we ponder the costly rescue of two California grays, we ought to keep in mind that at times sentiment is as important as logic

by Victor B. Scheffer

In the fall of 1988, all the world seemed taken by the plight of three young California gray whales trapped in the ice off northern Alaska. Even the American presidential election, for a few spellbinding days, took a back seat to the drama of the international effort to save the beleaguered animals. When a Soviet icebreaker finally cut a path to the surviving whales—the smallest had disappeared—an almost palpable sigh of relief could be heard around the globe.

Drowned out in all the hosannas and headlines over the rescue, however, was a troubling question, especially for those of us who have devoted ourselves to the study (and indirectly the preservation) of whales and other endangered marine mammals: Were the lives of the two whales worth the estimated $1.3 million it cost to save them?

No, argued those who would have put the money into research aimed at saving hundreds of other whales. Some pointed out that the very whales freed might later be killed by Soviet whalers! Yes, countered those who felt that it was a fair price to pay for all the goodwill toward

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wildlife generated by the rescue.

The debate was a familiar one, pitting logic against sentiment. It was also a kind that can never be satisfactorily resolved, for both logic and sentiment are necessary in the human enterprise.

On certain things, however, we can agree. The rescue underscored the enormous growth in popularity of marine mammals, both as an object of public attention and of scientific interest. When, in 1937, I joined a government party undertaking a biological survey of the Aleutian Islands, there were only a few dozen marine mammal scientists in the entire world, including those engaged in routine monitoring of the whale and seal fisheries. Now, 709 men and women are listed in the latest *International Marine Mammal Scientists Directory*. Federal agencies in the United States are spending about $14 million a year on marine mammal research, in addition to the substantial, although secret, amount spent by the Naval Research Laboratory. The National Marine Mammal Laboratory was established in Seattle in 1978, and the world's first professional group of its kind—the Society for Marine Mammalogy—in San Francisco in 1981.

The Growth of Public-Interest Groups

The last half-century has also seen an increase in nonprofessional, public-interest groups concerned with marine mammal conservation. Most were founded while the environmental movement was gaining momentum during the 1960s and '70s. Witness, among others, the American Cetacean Society (1967), Friends of the Sea Otter (1968), the Oceanic Society (1969), Greenpeace USA (1970), the Center for Environmental Education (1972), Monitor (1972), the Cousteau Society (1973), the Connecticut Cetacean Society (now the Cetacean Society International) (1974), and the Whale Center (1978). I offer three reasons for the upsurge in public interest demonstrated by the founding of these groups.

First, high-tech research employing instruments undreamed of fifty years ago is illuminating the ocean and its living communities. Whales and dolphins, whose biology was once known mainly through necropsy, are now being followed alive in the wild by radio signals relayed from satellites (article, pp. 14–18). Bowhead whales are counted by their distinctive voiceprints, even when they are hidden beneath ice. Humpbacks are recognized and catalogued as individuals by computer-assisted photography (article, pp. 37–44). The ability of the sperm whale to dive to depths of over a mile is revealed by sonar. Dolphin trainers question their "pupils" by sounds or hand-signals and the pupils answer by "telling" about objects in their pools. The ancestral bloodlines of whales are reconstructed through their DNA and by the microscopic patterns in their chromosomes. These are only some of the techniques that are now allowing scientists for the first time in history to penetrate the deeper mysteries of cetacean living and being.

Research and public awareness together compose a feedback system. Scientists discover an exciting fact about a marine mammal; the public appreciates the importance of the finding and expresses its willingness to fund further research through private or government channels; new discoveries are made and so on.

This is not to say that scientists and lay people always agree. When, for example, animal-welfarists object on ethical grounds to the clubbing of seal pups for the fur trade, scientists protest that the welfarists "don't have all the facts." The welfarists rebut that facts alone are an incomplete basis for management decisions; public preferences must also be considered.

Near my home in the Puget Sound region, a biologist holds a permit to take biopsy plugs from 45 killer whales in the enclosed waters of Washington. Although his research is well designed, many Washingtonians oppose it because the resident whales (known as pods J, K, and L) are perceived almost as an extended human family. They were exploited by whalers from 1962 to 1977 and they still suffer unintended harassment from boaters who approach too closely. "They've had *enough*," declares the director of the Whale Museum at Friday Harbor.

Second, opportunities for learning about marine mammals through the printed page, TV, and other media, have increased explosively, as have opportunities for travel to shores and waters where marine mammals can be seen. I attended a recent art show at which no fewer than 23 commercial artists displayed their paintings, photographs, sculptures, and tapestries—all featuring marine mammals.

Marine Studios, in Florida, was the nation's first oceanarium, opening its doors in 1938 to a few thousand visitors. In 1987, the attendance at all U.S. aquariums approached 19 million. (I have no separate attendance figures for oceanariums.) Having served as a naturalist on camera tours to Baja California, Alaska, and Antarctica, I can attest to the prime value of whales and seals in tourism. During the seven-year period, 1971–1978, when the business was growing fast, the mean annual increase in number of tourists was a lively 32 percent.

Third, today's interest in marine mammals is part of a larger interest in biotic communities everywhere. People are beginning to realize that, among the earth's myriad species, thousands are absolutely vital to the survival of *Homo sapiens* as an organism and thousands of others are vital to our culture. The term, "biological diversity," with its manifold implications for human survival, is entering the American vernacular. While a few of us focus on the imperiled status of the bowhead and right whales, the monk seals, the river dolphins, the Gulf of California harbor porpoises, and the California sea otters, we know that these forms are only a small fraction of the imperiled species of the world.

"Conservation," writes naturalist Peter Steinhart in *Audubon* magazine, "is often a

matter of helping our heads to catch up with our hearts, of developing the argument that explains an intuition we have about life."

The Marine Mammal Protection Act of 1972 was a clear expression of public interest in the future of marine mammals. To cite only one of its major accomplishments: it forced American fishermen to reduce the kill of dolphins in the tropical tuna fishery from 214,000 in 1970 to under 20,000 in 1987 (article, pp. 21–28). But certain marine mammal populations, spreading under protection, have begun to compete ever more seriously with valuable fisheries. Consider three examples:

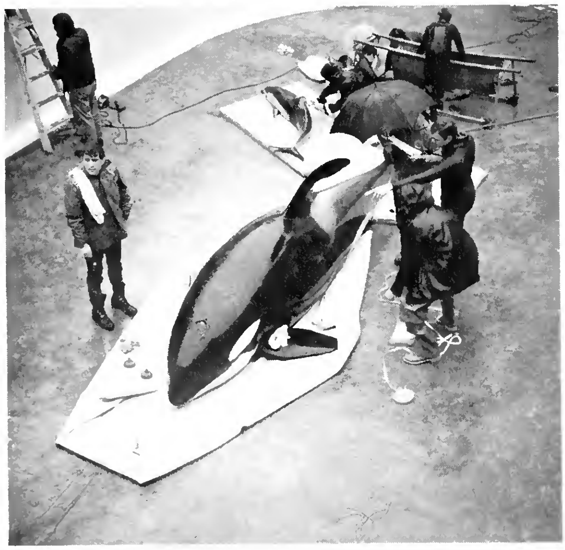
California sea lions, rarely seen in Puget Sound before the 1970s, are now preying on sea-run trout when these pool in winter below a fish ladder at Seattle. During the run of 1988/89, sea lions will take an estimated 900 of the 1,655 fish expected to arrive at the ladder; killer whales in Alaska, snatching sablefish (black cod) from long-lines, are causing an estimated loss to domestic fishermen of $2,300 a day; and Alaskan sea otters are eating yearly more than 200,000 tons of food—mostly shellfish—a bittersweet fact of life that angers the crabbers and shrimpers who take only one-fifth that amount.

There's another side to the coin, however. We humans relentlessly tax the resources of the sea while eroding the productive base of those resources through seawater contamination. The result is harm to marine mammals everywhere. On a small scale, the cause of the harm may be clear, as when a whale, dolphin, sea otter, or seal dies in a tangle of plastic netting. On a larger scale, the cause may be obscure. For uncertain reasons, the great Alaskan fur seal herd has fallen to about one-third its 1956 population level. Man-caused pollution throughout the North Pacific Ocean is a prime suspect.

Between People and Animals

More questions are arising from the interface between people and marine mammals. Thus, to what extent are we justified in using the mammals and to what extent in attacking them when they do harm? In considering a use, do we ask whether it is appropriate and necessary as well as humane? Should we continue to use marine mammals for luxury goods, and in the amusement business, and in military service? Each generation must find its own answers.

Wildlife management is the science and practice of maintaining a sort of "useful abundance" of animals. Although this definition is anthropocentric, it accommodates the view that some wild populations are used best when they are simply let be. I believe that we Americans increasingly favor benign, or nonconsumptive, uses of marine mammals as against uses that call for killing them. There is among us a widening sense that we need the beasts of the sea just as they are—alive and free. As we approach the limit of our ability to live within our own planetary means, we look admiringly at these creatures and see how easily they seem to live within theirs. They encourage our efforts to adapt, as they have done, to the world that we share, the world that gave us being, the only world that we and they are ever likely to know.□



Killer whales, like Skana at the Vancouver Public Aquarium, are causing serious losses to fishermen. (Photo by the author)

Acknowledgment

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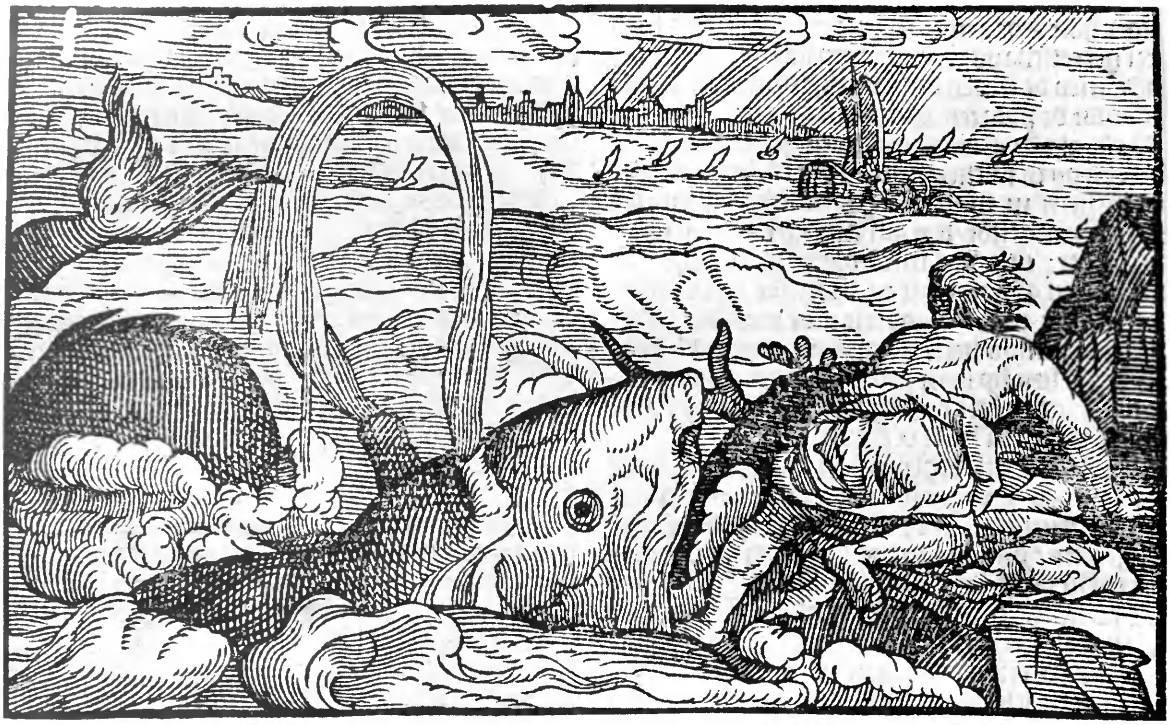
essay

THE WHALE,

A Large Figure in the Collective Unconscious



—or, A Freudian Field Day—

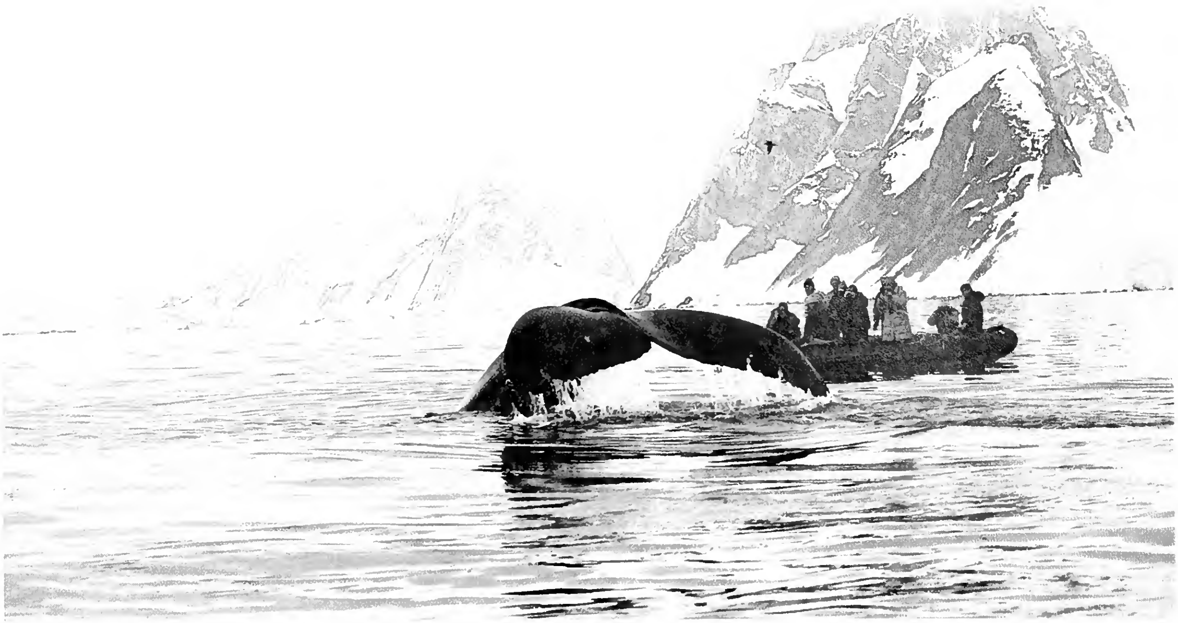
by T. M. Hawley

There I was, alone on a large island in the middle of a stormy sea. I had no food; weird fish would come flying out of the water, threaten me, and return to the depths; lightning such as I'd never seen before bolted down from the heavens and struck near my island. After some time a school of dolphins singing Gregorian chants brought me baskets of oysters and lemons to eat. One of them—one that somehow reminded me of my great-grandfather who died when I was eight years old—stayed awhile, then left, and came back regularly after that. At sunset one day I swam out to meet this dolphin, and as soon as I entered the water, my island changed into a sperm whale that came swimming upside-down after me. I saw its jaw, 50 feet long with hundreds of teeth, speeding at me like a cigarette boat. I closed my eyes and remembered Pinocchio; when I opened them again, my right arm was around the familiar dolphin and we were deep in the ocean. Although monstrous sea serpents would occasionally loom into view, the water was wonderful and we glided effortlessly through it. When morning came and I woke up, my wife and I were cuddled together like a couple of spoons.

Imagine what a symposium Sigmund Freud, Carl Jung, and Joseph Campbell could have staged on whales and dolphins. As they rise to the surface of the sea, blow, and return to the deep, they come looming into our dreams and myths from the far reaches of our individual and

(Above) Jonah Cast upon the Land, *an anonymous woodcut, suggests the necessity of spiritual protection on the great inner journey. (Courtesy of the Kendall Whaling Museum, Sharon, Massachusetts)*

T. M. Hawley is the Assistant Editor of Oceanus.



They are masters of the deep, and despite human technology they remain a powerful mystery. A humpback sounds in Lemaire Channel, off the Antarctic Peninsula. (Photo © by Colin Monteath, Hedgehog House)

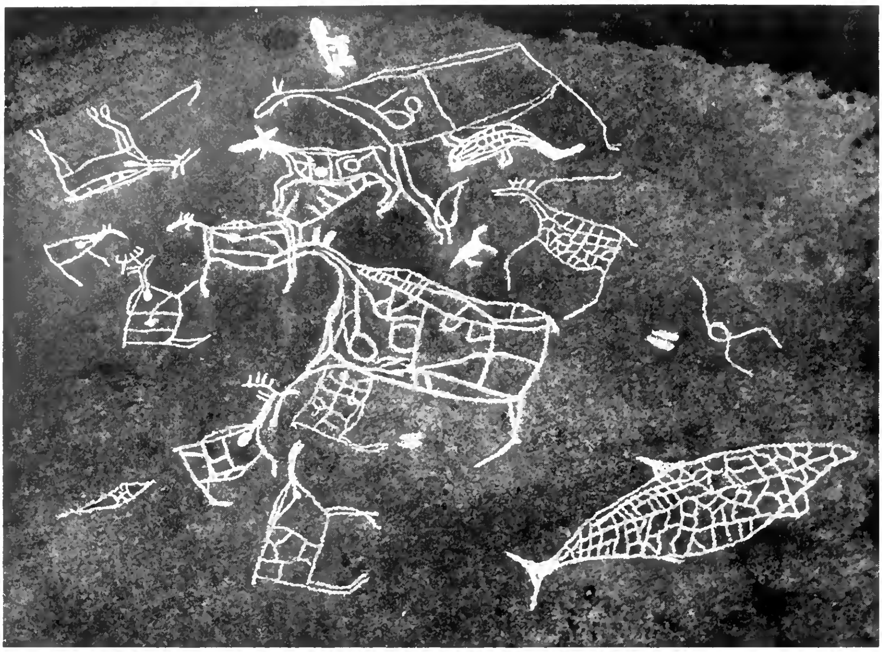
collective psyches. According to Campbell, the Polynesians describe dreaming as "standing on the back of a whale, fishing for minnows." And coastal societies from aboriginal Australia to Stone-Age Norway have found the titanic power and innocent sensuality of these animals so awe-inspiring, attractive, and ever present in their dreams that they came to play the most prominent roles in their myths and cosmologies. "The great whales" were among the first beasts created by the Lord of Genesis; the sea monsters lurking in medieval oceans, including Grendel and his mother, represented the wild and fearful power of the subconscious mind; harpooners, from the Nootka of the Pacific Northwest to Melville's Queequeg, evoke the heroic spear-throwing warriors of Homer's *Illiad*; and today, whales and dolphins are associated with everything from extraterrestrial intelligence to our last hope for accepting our ecological responsibility as "subduers of nature."

Along the coasts of the world, early societies saw the whale as a channel of creation and the ultimate anchor of the world's stability. As the largest creature on the planet and the seat of some intelligence, the whale evoked cosmological associations like those expressed in an Islamic myth that has a whale as the bedrock of the universe. In this scheme, the Earth originally sloshed around too much in the world-ocean. So Allah ordered an angel to hold up the ocean. The angel stood on a rock that was in turn lodged in the horns of a thousand-headed bull. The bull kept a steady footing on al-Bahmut, the cosmophoric whale.

An Inuit legend has it that the various whales of the Arctic—the bowhead, right, beluga, and narwhal—sprang from the severed limbs of the goddess Sedna. She had outraged her father by marrying a bird so he kidnapped her from her husband. On the voyage home her father threw her from his umiak and used his knife to prevent her from clinging to the boat. Sedna now rules over all the creatures of the sea, each one metamorphosed from a piece of her sliced off by her father.

In fact, the Greek words for dolphin, *delphis*, and womb, *delphys*, come from the same proto-Indo-European root, *gwelbh-*, and the Greek for brother, *adelphos*, literally means "born of one womb."

Poseidon, the Greek god of the sea, was faithfully served by Delphinus the dolphin in the important matter of obtaining a wife. Poseidon originally selected the immortal sea-nymph Thetis to be his spouse, but soon learned that any son of Thetis was fated to be greater than his father.



The image of the whale was firmly imprinted on the minds of Neolithic people, as this rock carving from Norway shows. (Universitetets Oldsaksamling, Oslo)

This prediction threw cold water on Poseidon's ardor, and Thetis eventually became the mother of Achilles. Poseidon's second choice, Thetis' sister Amphitrite, fled to the far western Mediterranean when she got wind of her lord's desires. But Poseidon knew the power of Delphinus' songs, and had the dolphin swim the sea in search of Amphitrite, and serenade her back to him. Poseidon was so grateful that he had the image of Delphinus forever set in the heavens.

Greek mythology is rich with the association of dolphins and music. The mythic hero Arion was a wealthy lyre virtuoso who happened to travel once with a boatload of unscrupulous mariners. They decided to get rid of him, but honored his request to play one last tune on the lyre. Arion knew the songs of the nearby dolphins, and when the sailors tossed him overboard, the dolphins carried him safely to the city of the would-be murderers. In the end, justice was done when the evil sailors returned home and found Arion waiting for them.

The myth of Arion is perhaps the earliest "lost sailor saved by dolphins" story we know of, and reports of such caretaking by small cetaceans continue—and so do the seductive powers of cetacean song. Roger Payne's *Songs of the Humpback Whale* was released in 1970, and has gone on to become the most successful nature recording ever. Judy Collins gives concerts accompanied by recordings of humpback songs, a technique also used by composer Alan Hovhannas in his symphonic creation *And God Created the Great Whales.* In 1979, *National Geographic* included a soundsheet of humpback songs in its January issue; the 10.5 million copies of this record represented the largest pressing of any sound recording to that point. Two spacecraft—Voyagers I and II, now in the outer reaches of the solar system and ultimately bound for interstellar space—carry recordings of human greetings in 62 languages with an overlay of humpback songs. As long as 2,000 years ago, Pliny the Elder wrote of how music is a bridge between dolphins and humans.

> *The dolphin is an animal not only friendly to man, but a lover of music as well. He is charmed by melodious concerts, especially by the notes of the water organ. He does not dread man, as though a stranger to him, but comes to meet ships, leaps and bounds to and fro, vies with them in swiftness, and passes them even in full sail.*

Why do we treat these songs as if they were cetacean psalmody? The deep longing in the human psyche to communicate beyond the species has been expressed since the earliest myths, and still has great power if the messages on the Voyager spacecraft—designed to last 1.2 billion years—are any indication.

For some reason, we really need to believe that we're not alone on Earth, let alone in the universe. With surprising credulity, respected examples of the popular press still carry reports that dolphin and humpback songs represent a facility with language perhaps as rich and complex as our own. They have a haunting beauty, to be sure. But the humpback songs we're all familiar with were recorded under conditions comparable to those in a submerged cathedral—miles away from the animals, in an area of steep underwater cliffs—fantastically exaggerating the reverberation of the sound. When the songs are heard from a distance of up

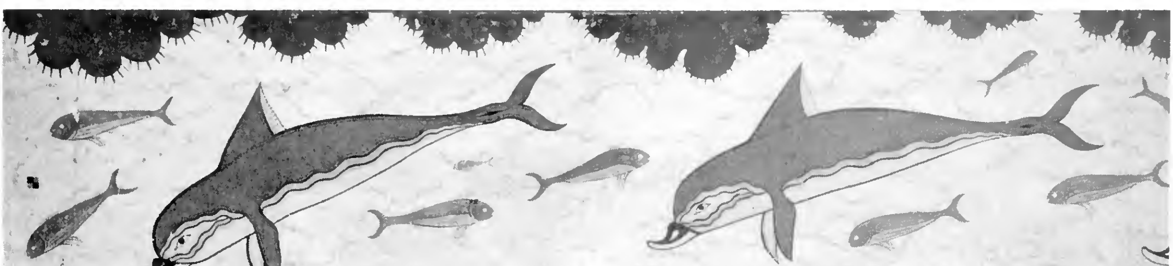
to a few dozen yards—the distance meaningful to the whales as far as we know—the echoing, entrancing calls compress into something that sounds all too much like the grunting of pigs.

The element of music touches on the sensuality of cetaceans, which surely goes beyond the sense of hearing. There is an ancient poem from a town, now a ruin on the Turkish Aegean coast, that sings of an erotic and tragic relationship between a dolphin and the most beautiful boy in that town. So sensual and horrifying is the poem's imagery that it seems to belong to the present century. The tragedy comes when the boy, in a fit of euphoria, accidentally impales himself on the dolphin's dorsal fin.

The sensual evocations of dolphins spoke eloquently to the builders of the ancient civilizations of the Aegean, known to the Egyptians as "The Sea People." And we know from Attic pottery and Pompeian frescos that sensual pleasure was openly celebrated by the pagan Greeks and Romans. Dolphins were usually represented in their mythology as intelligent and moral animals, given at times to intimate relationships with humans. The sensual importance of the animals is even borne out by how realistically they were portrayed from the most ancient times. In the Queen's room of the 3,400-year old Minoan palace at Knossos, Crete, there is a striking fresco of clearly recognizable *Delphinus delphis* individuals, along with sea urchins.

The myth of Arion is shown in this Greek coin, struck between 272 and 235 B.C. (Courtesy of R. Stuart Mackay)

In today's society that has returned to celebrating sensuality, we are again fascinated with these sleek and slippery mammals that playfully glide through the water, and seem to delight in erotic relationships with members of the same sex or family, and even with other species and inanimate objects. From Hollywood and Europe come popular films that exploit the amatory appeal of dolphins. Scientists investigating dolphin behavior agree with the dolphin trainer who says that her charges "spend a lot of time messing around." As we put this issue together, I was surprised to learn how ubiquitous all the combinations are. In Western Australia, young males are allowed entry into the clique of mating males only after what seems to



The Queen's Room of the 3,400-year-old Minoan palace at Knossos, Crete, is the home of this striking fresco, one of the finest representations of dolphins ever produced. (Photo by Michael Holford)

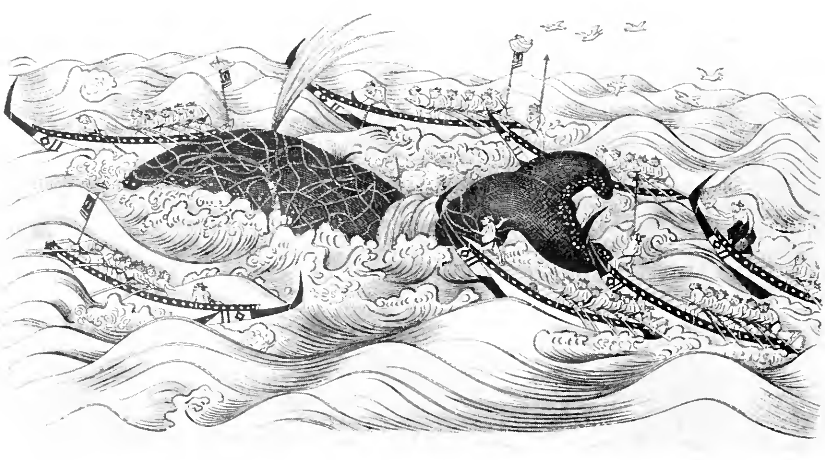
be a vicious round of hazing that includes the initiate's genital slit being the target of repeated attacks by the older males.

Aside from the sensual significance and appeal of cetaceans, especially dolphins, psychic and physical force has been the other great theme of whale symbolism. Until the Industrial Revolution encompassed whaling in the mid-19th century, the hunt for great whales—whether along inhabited coasts or on the open seas—had been an undertaking worthy of a Jason or Odysseus. Melville is of course the classic teller of this tale, but for more than 300 years before Ishmael signed on with the *Pequod*, Basque whalers roamed the waters around Greenland and Iceland searching for right whales, driven from the Bay of Biscay in earlier times. Job contemplated the might of Leviathan—*livyatan*, or "tortuous monster" in Hebrew—and Jonah experienced Yahweh's wrath and mercy by spending three days in the belly of a whale.

As Ishmael attended services at the Whaleman's Chapel in New Bedford on the eve of his great hunt, in other traditions and cultures there likewise has been a strong spiritual element in preparation for whaling. Ishmael was mesmerized by Father Mapple's fire-and-brimstone rendition of the story of Jonah. This tale has often been interpreted as the great journey of self-discovery, for if waves and tempests symbolize the unpredictable and wild imagery of our dreams and fantasies—our unknown selves—then whales, as lords of the sea, represent the possibility of understanding the subconscious. To approach and enter the whale is obviously not an errand for the faint-hearted; the commitment to the ultimate inner journey—known to monastic traditions throughout the world—has always been spoken of as requiring unwavering dedication and courage. Neither Jonah nor Pinocchio embarked on it voluntarily; both were driven by forces far greater than themselves, and in the end both were transformed by the experience. The enduring pull of this powerful idea—descending to the depths of one's being and returning to the world transformed—is evident by the continuity of the Jonah motif in art over the centuries. The terrestrial analog of this mythic motif is the hero slaying the monster. What makes the biblical Jonah so special, though, is the strong identification of the sea with the subconscious, and the titanic mystery of the great whales—where do they come from, what do they look like, and how do they rule over the ocean?

The Makah and Nootka were the principal whalers among the aboriginal Pacific Northwest Coast tribes, and the crucial, mythic importance of whales to their societies is manifest at every turn. Every newborn Makah was given a sliver of whale blubber to eat as a sort of baptism into the tribe. Harpooners were trained in their art—mechanically and spiritually—from childhood, for only after privileged communication with the spirit world was it possible to convince a whale to sacrifice its life for the good of the tribe. The chief had to take the first whale of the season. If he failed in this task any calamity might befall the tribe, and he was quickly deposed. In the days leading to a whale hunt, the harpooner would separate himself from the tribe for ritual purification, reminding one of the vigil of medieval men about to become knights. The harpooner offered prayers not only to the whale, but also to the wind and water deities. He would wear ritual clothing of fern fronds and body paint, and at times roll and splash in a special pool, scratching himself bloody with hemlock branches. The prayer to the whale was all-important, for it convinced the whale of the signal honor it was to be taken by the men of the tribe:

> *O mighty and fat whale!*
> *I am coming to give you what you long for,*
> *my sharp harpoon!*
> *Take hold of it and turn toward the men*
> *rowing out to meet you!*



The whale's strength, and the whalers' courage, are depicted in this traditional Japanese woodcut from a paper scroll. (Courtesy of the Kendall Whaling Museum, Sharon, Massachusetts)

A detail from a 1798 Japanese watercolor scroll, Twenty-three Varietes of Whales. *(Courtesy of the Kendall Whaling Museum, Sharon, Massachusetts)*

Hear them sing of your strength and majesty!
We will cover you with the bluebill duck feathers you desire,
the robe you are searching and spouting for over the whole world!

In Japanese folklore, the pride of the whale is told in a story involving the great Buddha, or Daibutsu, of Kamakura. The Daibutsu was cast in bronze in 1252, and originally was housed in a wooden building. It has been sitting serenely for more than 700 years, despite a terrific storm that destroyed its house in 1369 and a tsunami that took out the rebuilt structure in 1494—sitting serenely, except for one time, it seems.

A whale heard rumors of the Daibutsu's great size—it's about fifty feet high—but scoffed at them incredulously. The rumors persisted, however, and the whale's jealousy got the better of him. He persuaded a friendly shark to go and measure the bronze deity. The shark did his best, but had to convince a rat to do the actual measur-

The belief in monsters of the deep persists to this day. But in the 16th and 17th centuries, imaginative artists used "eyewitness" accounts to create an impressive menagerie. This composite incorporates the work of Olaus Magnus, Conrad Gesner, and others. (Courtesy of the Kendall Whaling Museum, Sharon, Massachusetts)

ing. The rat took 5,000 steps to get all the way around the Buddha, which translates to a circumference of about 97 feet. This was really too much for the whale, who still didn't believe that anything on Earth could rival his bulk, so he himself went to investigate. When he reached the shallow water near shore, he put on magic boots and walked up to the temple. He tried to get inside, but was too big for the entrance. A priest came out and asked the whale why he had come.

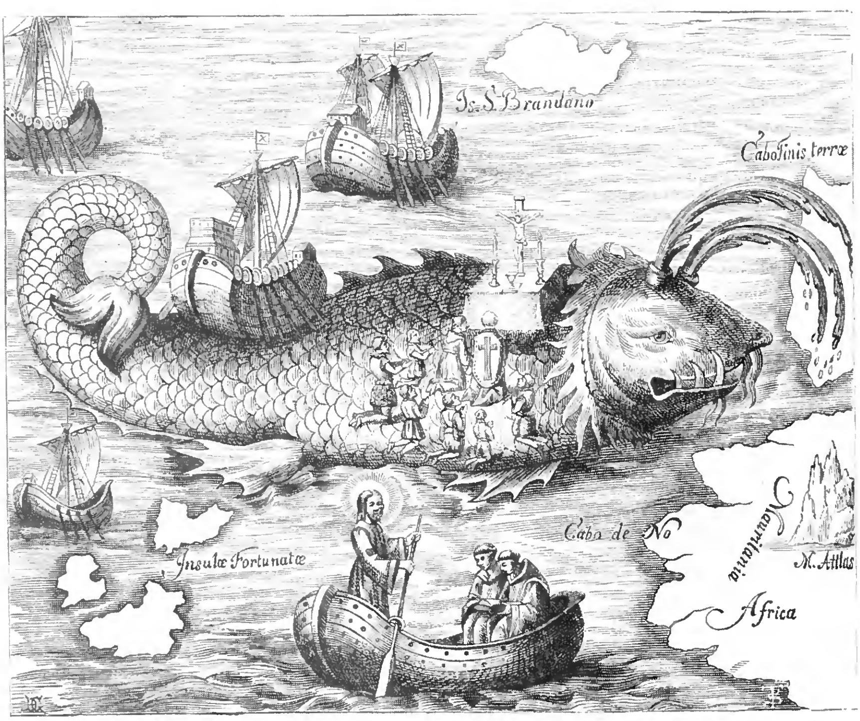
The whale said: "The little animals that live in the sea and on dry land insist on telling preposterous stories of a Daibutsu so large that it surpasses even myself in size. I know that there is nothing on earth that can match my bulk, and so have come to prove that these little animals are liars, and are merely jealous of my great size."

We can imagine how taken aback the priest must have been, but before he could stammer a reply to the whale, who stepped out through the doorway—stooping as he came—but the Daibutsu himself! In fact, the Buddha was surprised to see a creature so large as the whale, but calmly allowed the priest to measure them both with his rosary. The whale was able to return home happily, as his length was two inches beyond the Daibutsu's height. The Buddha, being perfect and not afflicted with undue pride, returned to his temple and reassumed his lotus position as he remains today.

Myths and folklore concerning frightening sea-beasts fill volumes. In the Western tradition, we've been hearing of them ever since Perseus came swooping out of the sky to slay the sea monster that was about to make a meal of Andromeda. The Norwegians have their kraken, a not completely malevolent beast. When he rises, he brings an abundance of commercially important fish along with him; but when he dives, he creates a whirlpool so strong that no nearby boat can escape it. The Icelanders tell of the fierce "red-headed" whale, that comes to capsize fishing boats and devour the fishermen in them. These mythical malefactors are said to have an excellent memory of where their previous feasts occurred, so these places were avoided by Icelandic fishermen.

It so happens that the artists of the Middle Ages and early Renaissance—when sea monster populations reached their highest, or pre-exploitation, levels—really went off the deep end when representing any sort of sea creature. The anatomically correct dolphin frescos and mosaics of ancient Greece and Crete gave way to drawings and paintings of hybrids still far beyond the reach of recombinant DNA methods. Instead of blowholes, whales might be depicted with what looks like the last few inches of a double-barreled shotgun sticking out of their heads. Throughout medieval and Renaissance times, and well past the beginning of the Industrial Revolution, they represented the crushing, irrational forces of nature that humans fought tooth and nail against just to stay alive for three or four decades.

Medieval monsters, not necessarily malevolent, show up as the island beast of St.



The Legend of St. Brendan: Celebration of Mass on the Back of a Whale. *This is a 19th-century copy of a wood engraving from 1621. (Courtesy of the Kendall Whaling Museum, Sharon, Massachusetts)*

Brendan. Today's scientific information on the typical cetacean's attitude towards humanity agrees with the disinterestedness of these accounts, but the medieval descriptions show a greater kinship with gothic gargoyles than with modern anatomical keys.

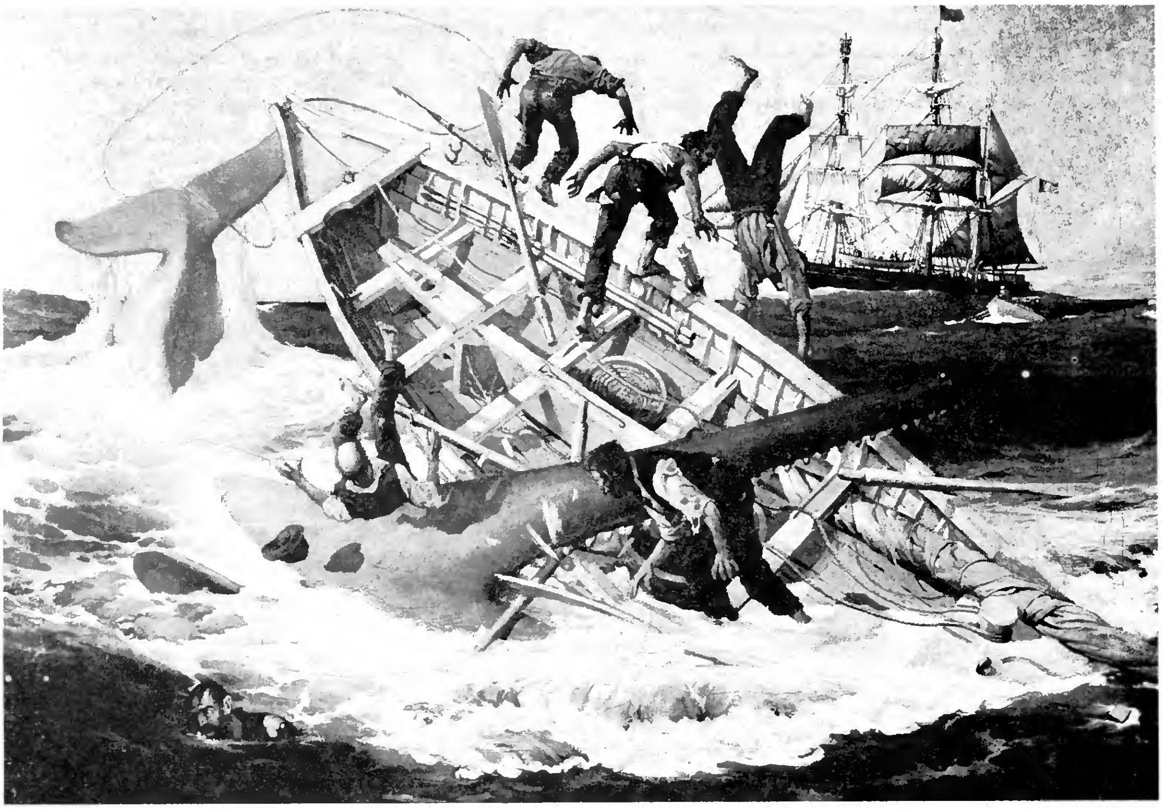
> *And then they sailed forth, and. . . at last they went upon an island weening to them that they had been safe, and made thereon a fire for to dress their dinner, but St. Brendan abode still in the ship, and when the fire was right hot and the meat nigh sodden, then this island began to move, whereof the monks were afeard, and fled anon to ship and left the fire and meat behind them, and marvelled sore of the moving. And St. Brendan comforted them and said that it was a great fish named Jascoyne, which laboureth night and day to put his tail in his mouth, but for greatness he may not.*

The St. Brendan story combines a wonderful array of symbols. As in Jonah, the presence of God (delegated to the saint) is necessary for a successful voyage to the limits of the self. But in this version, the whale—representing the subconscious—does a remarkable thing. By trying endlessly to put its tail in its mouth, it aspires to become like the Ouroboros, the snake that swallows its tail and symbolizes wholeness or self-knowledge. The Ouroboros was a prominent symbol in medieval alchemy, and inspired the 19th-century chemist Kekulé to deduce the ringed structure of benzene.

The place of sea monsters in humanity's imagination has largely been taken over by UFOs, the exceptions being Nessie and a few odd strays. And we know by now that the great monster is found in his most malevolent form within our own heads, it is our weapons of destruction that do his bidding. Perhaps this says something about modern humanity's estrangement from nature. As science and technology extend their claims of understanding and mastery of nature, the totemistic impact of creatures and other natural phenomena gets dissected away from, and dies of neglect in favor of, their utility as nutrition, sources of energy, or means of amassing wealth. Wolves are no longer a tangible metaphor of ferocity or the pack instinct, a terrorist attack or fanatical mass movements are more meaningful today. Even so, the pull of whales on humanity's emotions remains so strong that no expense was too great in order to save a few gray whales from what may have been the consequences of their own ignorance, and the Japanese and Icelanders are vilified around the world for continuing to tap what has been for centuries an important resource for them. These outpourings of emotion seem to say something about the value to humanity of preserving nature's totemistic impacts.

Will a total ban on killing whales perserve their totemistic impact? Or would such a ban have the effect of putting them in a zoo, where the submission of animals to humans is as obvious as anywhere? While they obviously cannot survive a reckless onslaught of technology—in the form of exploding harpoon heads, and factory ships with sonars and giant pressure-cookers for speedy whale processing—they ought not suffer the marginalization that cows or zoo inmates have suffered, finally being most recognizable as cartoon characters. Perhaps, ultimately our realization of the "subduers of nature" role means that the emotional or psychic weight of nature will shrink. Even so, the palpable association of whales with grandeur and strength might be preserved by

This engraving by the 16th-century Flemish artist Adriaen Collaert depicts Roman combat with an "Orca," that was described by Pliny the Elder in A.D. 42. (Courtesy of the Kendall Whaling Museum, Sharon, Massachusetts)



Should we return to small-scale, high-risk artisanal or sport whaling? Sperm Whale Upsetting a Whale-Boat, *by the early 20th-century American, Percy Elton Cowen. (Courtesy of the Kendall Whaling Museum, Sharon, Massachusetts)*

allowing more small-scale, high-risk, artisanal or sport whaling; it could provide a sort of elemental experience comparable to mountaineering or white-water boating. As the International Whaling Commission's present moratorium on commercial whaling nears its end, the issue of resuming any commerical operations gets more attention. To those who advocate total preservation, the recovery of previously threatened populations is a mixed blessing; because to those who advocate limited commercial activity, the recovery shows that stocks of some species can be successfully "managed." In any event, enough emotional impact remains to ensure that the decision whether or not to resume taking them will be based more on political sensibilities than on testimony from cetologists. □

Acknowledgments

My thanks to the staff of the Kendall Whaling Museum in Sharon, Massachusetts, especially Assistant Curator Joost Schokkenbroek.

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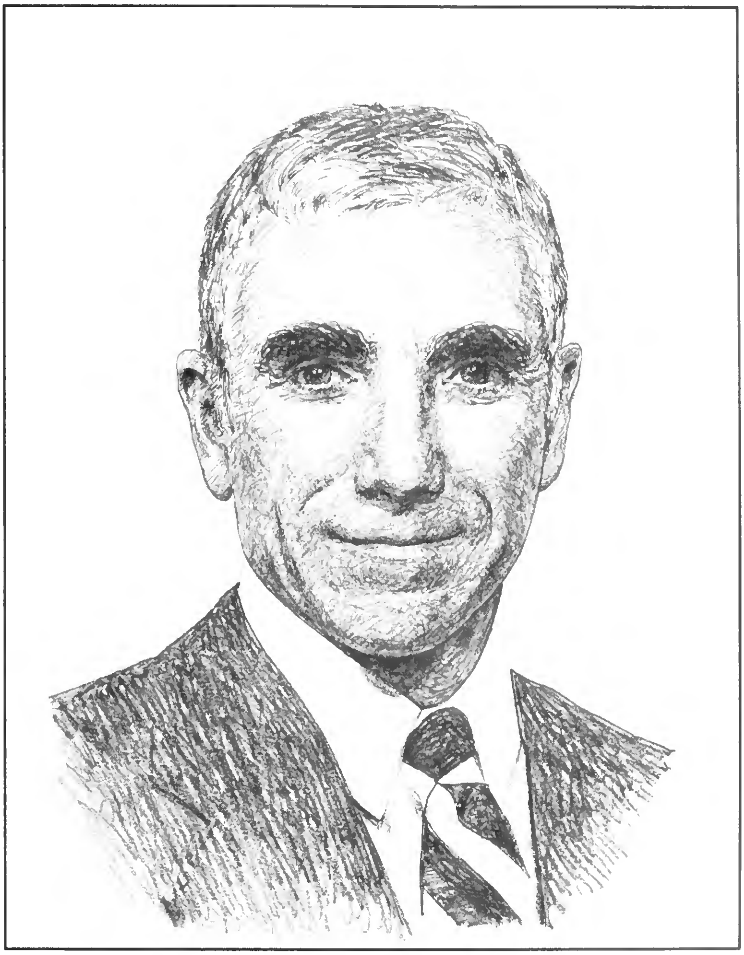
Craig Emery Dorman



Portrait by Dorothy Meinert

Flying High Cover

by Victoria A. Kaharl

For 26 years, five months and 11 days, Craig Emery Dorman met most of his working days in uniform. And for 12 of those years, they were largely spent in the dusty, cluttered "attic," the Pentagon's fifth floor (and, yes, its former attic). But on 1 February, Dorman, a rear admiral, retired his Navy blues and switched to a civilian headquarters: the stately old Cape Cod mansion known as Fenno House on the Quissett campus of the Woods Hole Oceanographic Institution (WHOI).

On that day, Dorman, 48, became WHOI's sixth director, succeeding in a line that includes such illustrious figures in oceanography as Henry Bryant Bigelow and

Victoria A. Kaharl is a science writer in residence at the Woods Hole Oceanographic Institution.

Columbus O'Donnell Iselin and, most recently, John H. Steele, who remains as President of the Corporation and as a Senior Scientist after serving 11 years as WHOI's director (box, page 126).*

Is Dorman going to miss the black tie and white shirt with the gold star and anchor insignia on his shoulders? "Not at all," he said. "I don't think I'm going to miss it one bit."

Dorman was "tremendously surprised" to be offered the directorship. And it was clear from an interview in his Pentagon office prior to his departure for Woods Hole that he's ready to confront the challenges—and opportunities—that await him.

In Dorman's view, oceanography is critical to solving some of the world's major problems. "The ocean is highly central to the issue of global warming, if it is in fact happening, and the role the oceans play in the total global dynamic, which certainly has to be resolved one way or other, is a major driving question," he said. "The question of ocean pollution control—what do we do with the mess we made and keep making worse? And finally our national defense: long strides have been made in submarine technology [by the United States and the Soviet Union] in the last few years, and that has caused the Navy to go back and ask some very fundamental questions about ocean processes in ways that we really haven't been forced to do since World War II.

"I see the needs of all three of these areas being very comparable and I see the role a place like Woods Hole can play. It has a reputation that's absolutely wonderful—it really does. I think we can take a more overt, or direct, leadership role in some of those areas. At least I'd like to see us do so."

There's every indication he will. As Program Director for Anti-Submarine Warfare (ASW) in the Space and Naval Warfare Systems Command, Dorman's post for the past dozen years, he guided scientists and engineers at laboratories around the country, including WHOI, in meeting the challenges posed by ASW. His work also included advising Congress on the avenues of research and engineering that the country should follow in the best interests of national security.

As a doctoral candidate in the joint MIT-WHOI oceanography program, Dorman (seated) didn't hesitate to get his feet wet when the need arose. (Photos courtesy of Cynthia Dorman, except where noted)

Quality of Leadership

Dorman's friends and colleagues tend to speak of him in superlatives.

"An outstanding person, very smart and very energetic, very far-seeing," said Ed Frieman, director of the Scripps Institution of Oceanography, whose friendship and professional relationship with Dorman goes back more than a decade.

Another long-time associate, Scripps Physical Oceanographer Walter H. Munk (profile, *Oceanus* Vol. 26, No. 4, pp. 57–62), likens Dorman to WHOI's second director, Columbus Iselin. "I don't wish to really compare the two—their backgrounds are so different," Munk said. "But they both have whatever it takes to create loyalty among those they work with. They both have that magic quality of leadership."

One of the highest compliments came from Dorman's Ph.D. thesis advisor, Erik Mollo-Christensen, who was questioned about him by the internal WHOI committee that

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*The past directors were:
Henry Bryant Bigelow (1930–1939)
Columbus O'Donnell Iselin (1940–1950, and 1956–1958)
Edward Hanson Smith (1950–1956)
Paul McDonald Fye (1958–1977)
John Hyslop Steele (1977–1989)

investigated the candidates for director. "I told the guy on the search committee that I wondered if it really was in the best interests of the country for him to leave the Navy," said Mollo-Christensen, now at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "He is very bright and he isn't scared of anything. He took Orszag's math course, which separated the men from the boys."

Steven Orszag was a Massachusetts Institute of Technology (MIT) math professor whose legendary course instilled fear in students.

An only child, Dorman was born in Cambridge, Massachusetts, to Betty and Carlton Earl Dorman, a meat broker who worked at Fanueil Hall in downtown Boston. When he was in his early teens, the family moved to Bedford, then still a farm town in the historic Concord-Lexington area. His was the first graduating class from Bedford High, in 1958.

He went on to Dartmouth College in Hanover, New Hampshire, where he was elected to Phi Beta Kappa and president of his fraternity.

Because his French was good enough to exempt him from one term's language credits, Dorman decided to try another language, Russian. It was a "good tough class," he recalled, but after five semesters, he had second thoughts. "I got slightly terrified," he said. "We were assigned to do a sight translation from ancient Cyrillic to modern Russian. One guy in the class could do it. I figured if only one could do it, I was pretty far behind, so I left at that point."

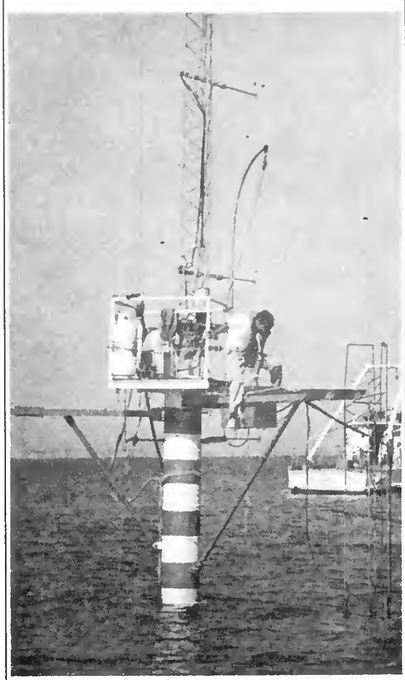
What Dorman didn't say is that he earned four As and a B in his Russian courses, not to mention a fistful of As in most of his other courses. He graduated summa cum laude in 1962 with a bachelor of arts in geography.

The same year he married his college sweetheart, Cynthia Eileen Larson, from Bedford, and was commissioned in the U.S. Navy. He left his 19-year old bride on Waikiki, where they had honeymooned, to report for duty on a frigate bound for Japan.

Eighteen months later, Dorman was assigned to Underwater Demolition, and eventually became a SEAL (Sea Air Land), the Navy's equivalent of the Green Berets. He led a SEAL unit in Vietnam for a few months. "It's a good outdoor life," Dorman said, grinning at the memory of jumping out of helicopters through skies of flak.

In 1968, Dorman, by then a lieutenant, graduated from the U.S. Naval Postgraduate School in Monterey, California, with a master's in oceanography. His thesis dealt with the movement of sediment through the ocean. The following year he matriculated in the year-old Joint Program in Oceanography of WHOI and MIT. He was one of four naval students assigned to Mollo-Christensen, an MIT physical oceanographer.

"He was an unusual Navy student because he got along with civilians," Mollo-Christensen said. "With my other Navy students, there was a slight cold layer. One of them handed a list of instructions to the skipper of a boat we were using that started with breakfast to be served at 5 A.M., and when to start up the engines—you know, warm up the diesels for two hours. The skipper came to me and said, 'What do I do?' I said, 'Don't worry, I'm your commanding officer.' Craig got along with everyone. He has the sense not to do stupid things."


The monster spar buoy he co-designed.

Heavy Machinery

Dorman spent several months in Woods Hole and on the Elizabeth Islands working with a spar buoy he designed with Mollo-Christensen to take current speeds and other measurements. Building and deploying the prototype, which stood about 120 feet, was a major undertaking that involved heavy machinery. The local marine contractor, Dan Clark, supplied the crane and barge, and the men to run them.

The 30-year old navy lieutenant became a fast friend of Clark, who is something of a legend in Woods Hole, as much for his business sense as his kindness and long white beard yellowed from the stogies he smoked.

They were working on the buoy in Naushon harbor, across from Woods Hole, when Clark sneaked off to call Mollo-Christensen to learn how Dorman had done on the general exams for his doctorate. The results weren't in, Mollo-Christensen said, call back in a few hours. Clark did, and at the good news hid some champagne in the small inflatable boat they used to ferry back to shore. When Dorman called MIT for his test results, he jubilantly shimmied up the 100 feet or so of Clark's crane and whooped, even before he had a sip of the champagne. Said Clark: "He went right nuts."

Dorman had a reputation as an excellent diver. One day in Woods

Hole, Mollo-Christensen's young daughter, pointing to Dorman, asked her father, "Is that the man who jumps overboard with the knife in his mouth?"

She had watched her father and his student tow a small instrumented catamaran off Cuttyhunk, one of the Elizabeth Islands, when suddenly a wave swamped the craft, forcing it under. Dorman, his teeth clenching a knife, followed it not a moment too soon, and managed to cut the catamaran free.

"Craig said he had to walk down the keel while cutting the ropes, and to push off before hitting the propeller," Mollo-Christensen said. "It was really quick thinking. If any one of our underwater instruments was out of whack, he'd jump in and fix it. It was a little bit of a joke how we couldn't keep Craig out of the water."

Two and a half years after joining the Joint Program, Dorman defended his Ph.D. thesis on wave generation (using data from the instruments on the spar buoy). Most students took about five years.

"When we reviewed the progress of the students," said WHOI Assistant Dean Jake Peirson, "his progress amazed us. This guy seemed to be flying through the program."

Dorman still moves at flank speed. He also likes to walk the deck planks, as he puts it. "I don't like sitting in an office. I like to get up and get out and see the people. Offices are places where you think quietly and sit and write. If you need isolation that's a good place to hide, but certainly no place to find out what's going on."

He won't miss the secrecy that most of his Navy work involved. Neither will his wife.

"This is a bit of a closed environment here and I can't really share it with her," he said in his Pentagon office. "I've missed that. I think she'll have more fun. She can see what I'm doing and we can talk about it. That'll be fun."

Given the nation's slip-

A happy exchange with predecessor Steele. (Photo by Rob Brown, WHOI)

page as a world leader in technology and the need for wresting more and new information from the ocean, Dorman predicted more applied work for WHOI.

"The whole issue of national competitiveness is going to be a big driver for us," he said. "That means an expansion on the traditional basic scientific pursuits, and endeavors to more of a merging with technology. I think science needs more advanced technology. We need better ways to get information from the ocean. That implies a resurgence in ocean engineering. Woods Hole has always done an awful lot of ocean engineering for all of the various scientific disciplines. I see it doing more."

"I think we need to offer some of our scientists the opportunity to do more classified work, if for no other reason than that there are many good science questions being asked and good scientific work being done in the classified world," he said. "A good deal of the work being done in SDI [Strategic Defense Initiative or 'Star Wars'] is classified but let's face it, it is really pushing the technological and scientific edge."

Applied work, however, should not diminish WHOI's major strength in basic scientific research, Dorman said.

"About the only place I think where people still feel we as a nation have a good strong lead is in basic science," he said. "I, quite frankly, am concerned that this may erode as time goes on. I'm not convinced that in all aspects of science the United States is well out ahead, either.

"We're faced with a host of problems that are related to areas that we have expertise in—again, a combination of global change, pollution, and military and defense needs. When you're an expert in those areas, you have a responsibility. Woods Hole is in itself a valuable national resource. It's the best in the world. That implies a set of responsibilities to the world, to the nation."

Funding for growth and new directions of research probably will have to come from nontraditonal sources, such as NOAA or NASA, Dorman said. "The pot is only so large both at ONR [Office of Naval Research] and NSF [National Science Foundation] and we probably get our fair share."

WHOI's scientists are responsible not only for choosing the research topics they wish to pursue, but also for bringing in their own funding in the form of grants, usually from ONR or NSF. Unlike other institutes such as Scripps, which is part of the California state university system and benefits from some state funding, WHOI depends entirely on philanthropic and federal sources.

"The scientists are the guys who pay my salary. My job is to fly high cover," Dorman said, using the analogy of the jet fighter who flies lookout. "One guy needs to be up high looking out for the bad guys coming. My job as the director is to watch for the big holes. That's been my job [at the Pentagon], to find the big holes, the big opportunities, to move things gently, with a willingness of the

people being moved in broad general directions.

"I'm not used to giving orders. It's not that I don't have strong beliefs and strong feelings, I do. It's not because I'm necessarily nice. My job in the Navy has been to try to formulate the general approach to solving large problems—what are the technologies that should be applied, how do you develop those technologies, how do you acquire those capabilities—and in trying to form the broader aspects to solutions, you don't end up with pinpoint solutions, but ideas and thoughts.

"I don't necessarily believe in consensus, but I do believe that if you're working toward an institutional goal, an overall objective, then you've got to obtain the desire and commitment of all of those working toward the goal. They need to be a part of it.

"I've found that once you've identified in general where you want to go, there are usually about 10 to 15 ways to get there; and in most cases, it's best to let the guy who's really doing the job figure out his way to get there. I've found that I do better by working with the folks who are working for me to identify the general goals and directions and then helping them to figure out the best way to accomplish these things."

Twelve-hour Days

In Washington, Dorman got to work just before 7 A.M. and left just before 7 P.M., a 12-hour-a-day habit he picked up from his Joint Program days at MIT. "You get in before the traffic and you go home after the traffic," he said. "I can do 12 hours. I'm blotto after that."

There was also another reason. "We started coming in early because the kids went to school early and we lived in North Arlington, close enough [to the Pentagon] so that Cynthia could drive me to work. That way she got to keep the car and I didn't have to worry about parking."

With wife Cynthia and sons (from left) Clifford, Curt, and Clark.

The children, three boys, are grown. Clifford Ellery, 25, who was born the day President John Kennedy was shot, is a chemical engineer. He works in the late Admiral H. G. Rickover's old shop. His wife Alice is a cryptographer in Navy Intelligence. Clark Evans, 23, is also an engineer. He and his wife RuthAnne work at the Center for Naval Analysis. However, the adage "Like father, like sons" doesn't fully apply, Dorman said. "They're engineers; I consider myself more of a scientist."

The family exception is Curt Emerson, 20, a "free spirit" (in his father's words) studying biology at the University of Arizona.

"After two and a half years he's a junior," Dorman said. "He's very independent, been going to Europe on his own since he was 14. He's much more liberal and has more fun than his brothers. He'll probably get into ecology and be a tree-hugger of some sort. I'm a tree-hugger myself."

The family tradition of first names beginning with a "C" and an "E" began with Dorman's grandfather Charles Edward. It just so happens that Cynthia's middle name is Eileen.

Dorman, at 5 feet 9 inches, is trim and compact; he keeps his greying hair cropped short. The bushy eyebrows are still black. Occasionally his teeth bite a slim cigar, a taste he aquired from Dan Clark. But Dorman doesn't smoke, he chews.

His idea of a vacation is *not* leaving winter snow and cold behind for the bath-water tropics of Cancun.

"*No*, cannot do that," he said. "That is not fun. Drive me nuts. You couldn't *make* me do that."

But if worse came to worst, he'd make the best of it and jog on the beach.

When was the last time he took a vacation?

"A true *vacation* vacation?

He thinks but can't remember.

"I don't like doing nothing."

Asked what he does to relax, he replies: "I work out. I read."

These days he's reading medieval history.

The time of the plague?

"Right," he says and laughs easily. □

Getting Back the Union Card

Even though he has yielded the director's chair after 11 busy years in that demanding job, John H. Steele, at 62, has no intention of abandoning Woods Hole—or slowing down.

"I'm rediscovering that research still can be great fun," Steele said during an interview in his new office in Crowell House, home of WHOI's Marine Policy Center. "I expect to enjoy myself enormously in getting back into science."

A mathematician and biologist by training and widely acclaimed for his investigations of marine food chain dynamics and ocean ecosystems, the Edinburgh-born Steele wryly suggested that he had been slipping as a scientist ever since he got into the managerial end of the profession—first as the deputy director of the Marine Laboratory in Aberdeen, Scotland, then when he was summoned to WHOI in 1977.

"Now," he added, with a twinkle, "I want to do some writing—scientific papers and that sort of thing—so I can get back my union card [as a scientist]."

Not that anyone thinks the Alexander Agassiz medal-winner really lacks scientific credentials. Last year President Reagan appointed him to the prestigious Arctic Research Commission. And in his new role as a Senior Scientist attached to the Marine Policy Center, he'll be engaged in its far-ranging policy analyses.

High on Steele's agenda is an exploration of the increasingly important relationship between science and public policy. "We've seen rising public concern about the possibility of global warming," he said, "but a critical and largely unexplored factor remains the oceans. With their great reservoirs of heat and moisture, they pose the greatest long-term uncertainties for those trying to devise policies to meet the anticipated changes."

Looking toward new horizons. (WHOI)

He also wants to encourage more interaction between ocean scientists and those who practice their profession on land. Toward that goal, he organized a conference of marine and terrestrial ecologists for Santa Fe, New Mexico, in March, 1989. "One nice thing about the meeting is its locale," he said. "It gives me a chance to look at a little more of the interior of the country."

On the Dinner Circuit

Steele won't be entirely free of executive responsibilities in his new scientific life. He was recently re-elected President of the Corporation, a post that will require him to be a public spokesman for WHOI, the country's largest independent center of oceanography, and go out on the luncheon-and-dinner circuit to drum up financial support. "Private contributions are extremely important to us," he explained, "because they help keep scientists off that terribly draining treadmill of federal funding."

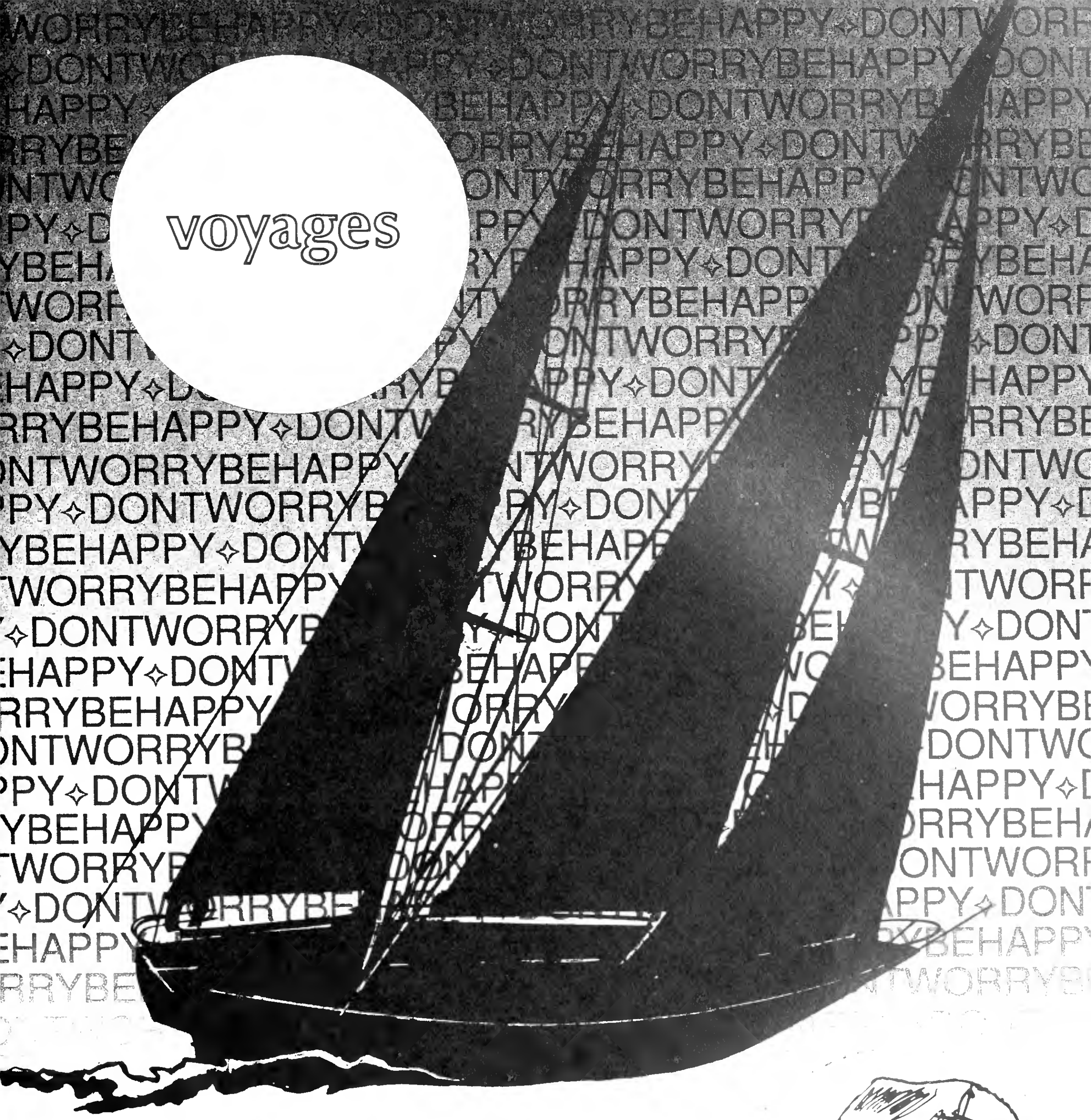
Even though they've turned over the director's residence, Meteor House, to their successors, Steele and his wife, the former Margaret Evelyn Travis, haven't moved any farther than their co-op in Falmouth. Still, they expect to make occasional visits to their son, Hugh, an electronics engineer in London, and to their hideaway cottage in Aberdeen. "A great place to write," said Steele, who produced his treatise The Structure of Marine Ecosystems *(Harvard University Press) there. He also hopes to do more sailing in his 19-foot sloop* Gwerfie Goch *(named after his wife's hometown in Wales).*

Steele, characteristically, declined to reel off a list of achievements as director; as those who've worked with him know, he's too modest for that. He would only note that WHOI's budget and endowment had risen "substantially" and that he had left the institution "fiscally strong." Also, there was a not-inconsequential amount of bricks and mortar, including construction of a new home for the Chemistry Department, the Paul B. Fye Laboratory ("It's architecturally as well as scientifically pleasing," he said); the McLean Laboratory, and the Coastal Research Laboratory, as well as several expansion projects still under way. He considers his main achievement "the tremendous output of science" during his term, which, he said, should ensure WHOI's continued scientific leadership as it confronts "the challenges of the future."

Was he leaving the directorship with any personal disappointments? Well, perhaps. "I wish I could have gone to sea more on our research ships." Then after a moment's pause, he added, "Maybe I can now start making up for that."

—FG

voyages



An Odyssey of Self-Discovery

by Eric Best

On a single-handed journey from San Francisco to Hawaii, a New England-born sailor learns he must master more than his boat and the seas

Illustrations by Sig Purwin

The final goodbyes are finished. I have slipped away from Pier 39 to a nearby marina for last-minute packing and preparation, and to escape the attention of close friends bearing good-luck charms, books, food, and emergency equipment. The detachment I had set out to find I have finally brought upon myself. My hands shake as I try to open the padlock on the main hatch for last time.

Alone at last, I am afraid.

What if I can't calculate the course into Honolulu from sextant shots of the sun? What if I lose the rigging in violent weather? What if I am hurt, unable to call for help? I had promised myself to leave San Francisco on the evening tide, to sail far enough out at night so I do not see the land drop away behind. All my adult life the fear of solitude has kept me from this or some journey of its kind, where I might see myself clearly, stripped of companionship and the voices that fill every day.

There is so much I do not know, as I have been warned. ("You're out of your mind," my father said. "You haven't sailed enough in the open ocean.") His words carry a particular sting because I am relying on small-boat sailing and summer coastal cruising in New England as a teenager, and several weeks of day-sailing in San Francisco Bay during the last two years.

Behind and below my pelvis now I feel the familiar sensation that drains my legs whenever I look down from a height. The key jams in the lock, like a sudden triumph of my subconscious. The padlock clatters against the steel, then opens.

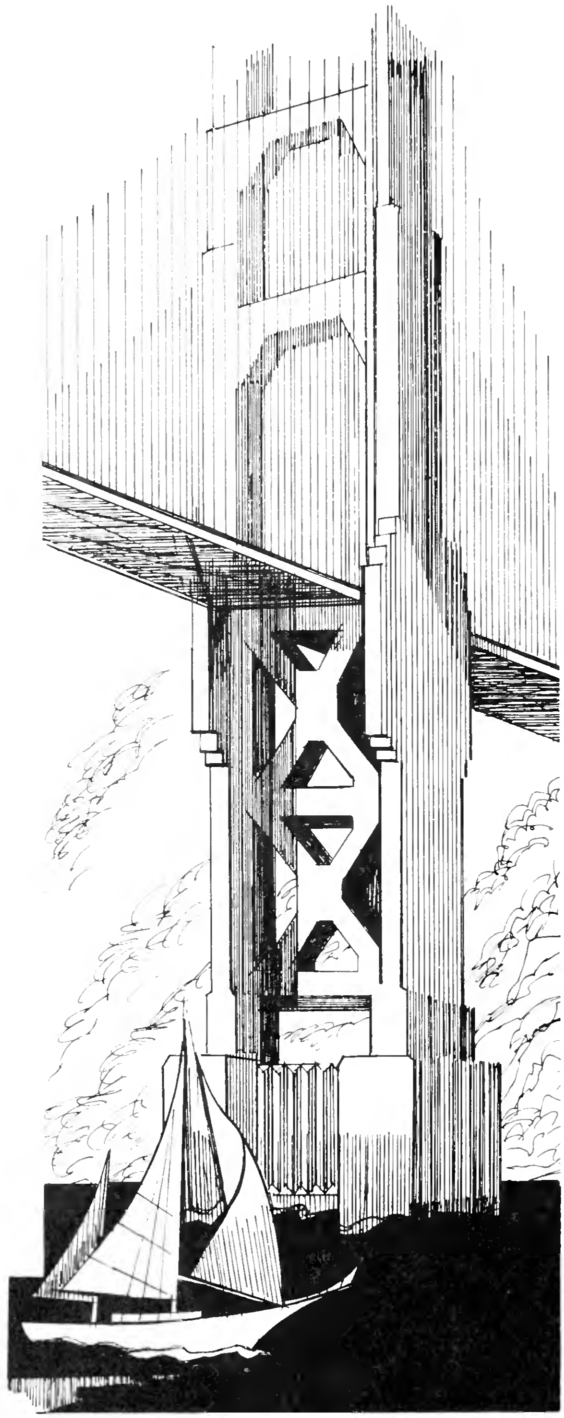
In the dark mahogany cabin, *Feo* is silent and nearly motionless on gentle harbor swells. She is a 47-foot steel ketch in the double-ended "Joshua" design that sailor-author Bernard Moitessier piloted in 1968 and '69 when he became the first solo sailor to circumnavigate the globe nonstop.

Feo has herself rounded the incomparably treacherous Cape Horn under a single hand—even survived a 360-degree rollover there, undamaged—and she has endured oceans in their highest moods from the Mediterranean to the South Pacific. I sense she has been waiting for another ocean journey since I bought her from an adventurous Swiss couple two years before. I am counting on her to know more than I do and to get me through whatever bad times may come.

The rare hurricanes off Mexico almost never push far enough north or west to be a problem in June, the most favorable time of year for a San Francisco-Hawaii crossing. The Pacific high-pressure system between the mainland and the islands, a huge meteorologic doughnut with clockwise winds around a center of calm, promises fair breezes south and then west all the way to Honolulu.

"Go south 'til the butter melts and turn west 'til you hear ukulele music," a waterfront regular has said. In moments of doubt I will repeat this mantra of simplicity.

I had expected to feel something dramatic



Eric Best is a San Francisco journalist and sailor. This article originally appeared in the San Francisco Examiner, *with whose kind permission it is reprinted.*

as the Golden Gate loomed overhead and the Pacific expanded, 2,100 miles to the next landfall. For months I had anticipated this during the reconditioning of *Feo*'s masts and rigging, though I had sailed no farther than the Farallone Islands, 20 miles offshore. This plunge into the ocean alone, dreamed of in fear and fascination, had passed through stages of imagination and self doubt, and had overcome resistance and obstacles. There was no turning back now from the limitless water and its uncertain promise to divulge some of its secrets—and, I hoped, illuminate me in ways I could not anticipate.

The fear that had gripped me earlier was gone, replaced by a heightened sense of my own demands, and *Feo*'s. I had to keep myself well fed and rested—cook before I grew lightheaded, sleep before I became exhausted. Whatever this unfamiliar sky might bring, I knew I could not afford to get caught with too much sail up. Even with a mechanical wind vane to steer the boat, I could not leave the course unattended for too long.

The ebb tide had begun to slacken as I cleared the Gate in a mild head wind under sail and power, the smell of hot engine oil rising into the cockpit. The returning flood would hold me back as I tried to get clear of the three major shipping lanes that converge just off the mouth of the bay from the north, west, and south. I had wanted to be well beyond the procession of freighters moving in and out before nightfall.

The sun fell into western haze, encircled by a blurred, rose-colored ring, a symptom of rain to come. Luminous and leaden clouds swept in from the ocean to Mount Tamalpais and the long, implacable rise and fall of the ocean replaced the short rhythm of the bay.

The ridge that descended from Mount Tam toward the water profiled a bearded man lying on his back, hands folded on his chest, at peace. His head became Point Bonita as I approached its dolorous, offshore bell. This at last was my point of departure from the city. The metallic "clang, bong, clang, bong" faded, and with its fading came the sense that I was disconnected from my daily life, freshly open to the universe.

In the gray light of dawn I am braced in the bowsprit to change a sail, the safety harness around my chest clipped to the rigging. I plunge toward the water and rise again in seas that have built through the night and now loom at twice my height. The tower light at the Farallones, outermost beacon of California, has long since receded. *Feo* has driven steadfastly through the darkness as the wind has risen.

I have not yet slept.

Before midnight I had come on deck to confront the lights of one freighter to the northwest, another to the west, converging on me. In the darkness, the exact distance of lights is uncertain, their heights unknown. I radioed a message to "any freighter in the vicinity" in case their radar had failed to detect me.

No one answered. I started the engine to boost my speed by a knot or two, and pushed the throttle up to full. The engine died suddenly, but restarted, a faint smell of oil rising again. I could see then the ships would pass easily at a distance, a false threat, and felt a rush of embarrassment to have announced myself on the radio.

As I had feared, one of the mainsail slides jammed on the way down, and shortly before dawn I abandoned any effort to reduce the mainsail area with a second reef, hoping the wind might subside. Instead it continued to rise, now up to about 25 knots. As I wrestled the big jib down onto the bowsprit, a gust of wind snatched the sail bag from my hands and blew it off to oblivion.

By late afternoon the upwind skyline has turned sickly yellow-gray and swollen, bunched together as if hiding something inside. *Feo* has been rolling her leeward rail under with a violence that shatters one coffee cup on the cabin floor and catapults the teakettle off the stove onto my chest—luckily just before the water boils.

Breaking seas occasionally strike along the windward deck, rushing aft and forcing themselves in small explosions under the edge of the main hatch and down into the cabin. I find some plastic packing material and fashion a crude gasket that makes the hatch nearly watertight.

The wind has risen to 30 knots, enough to pile seas to 20 feet high from peak to trough. I force myself to turn *Feo* up into the seas, which are more than twice her height, to take the strain off the sails. She waits, bucking and pitching, as I jack the mainsail up and down to work the slides past the sticking points. At last I have the big sail down and furled, leaving up only a small jib on the bow and the small mizzen at the stern.

Then we are off again across the darkening, roiled seas, which rise suddenly like giant sculptures, thrown up only to collapse again of their own weight and vanish into a sprawl of froth. In the distance they assume the forms of sudden ships, sails, rocks, and promontories, figures detected out of the corner of the eye but elusive, a tease to the imagination.

In the crashing noise and motion below, I study the loran. Concerned that I might not master celestial calculations on my own, I had installed the instrument in the last week before leaving and assumed I could decipher its various functions in the early days of the trip.

Through the next day I am buried in manuals, ocean charts, estimates of speed and distance, and the effects of deviation in my compass, which tells measurable lies about our true direction. The natural magnetism in the boat is responsible for this, a shifting degree of error that must be part of each new course.

I check the bilge and find a foot of yellowish water where the steel innards are usually bone dry. I pump it out quickly. Where did it come from? Is *Feo* leaking? For an instant, I see

her sinking, and picture myself trying to cut the dinghy free from its lashings on deck.

The port side has been heeled underwater for hours, and I conclude the water has either come in around the bow anchor chain as seas break over the deck, or that it has leaked back into the bilge from an outflow line as *Feo* repeatedly rolled her rail under. It will turn out that I am wrong.

I have napped only a few hours in the last two days and cannot face a night of staying awake to watch for freighters. I switch on the running lights at the top of the mast and the steaming light lower down that illuminates the jib and makes me ghostly visible in the dark. How foolish is my freighter fear in this plain of water! The intersection of a cargo ship and a boat as small as mine is so hugely, mathematically improbable.

At dawn I come on deck to make a routine inspection of the rigging and spot a grotesque tangle of lines high above my head. The halyard for the idle jib has come loose, risen halfway up the mast, then intertwined itself with the mainsail halyard. The tangle is looped into the stays that support the mast, and obviously can't be freed from the deck. Now the mainsail and one jib are both useless unless I climb high up the mast.

The wind has not fallen off and *Feo* is still pounding west under just the leading jib and the mizzen sail at the stern. The loran during the night has claimed speeds up to 12 knots, faster than *Feo's* hull shape should allow her to travel.

I stare up at the clot of line and wire, contemplating my phobia of heights. This tangle can be untied only if I climb 15 feet above the deck, stand on the lower crosstree, where I can possibly reach it with one hand if I stretch.

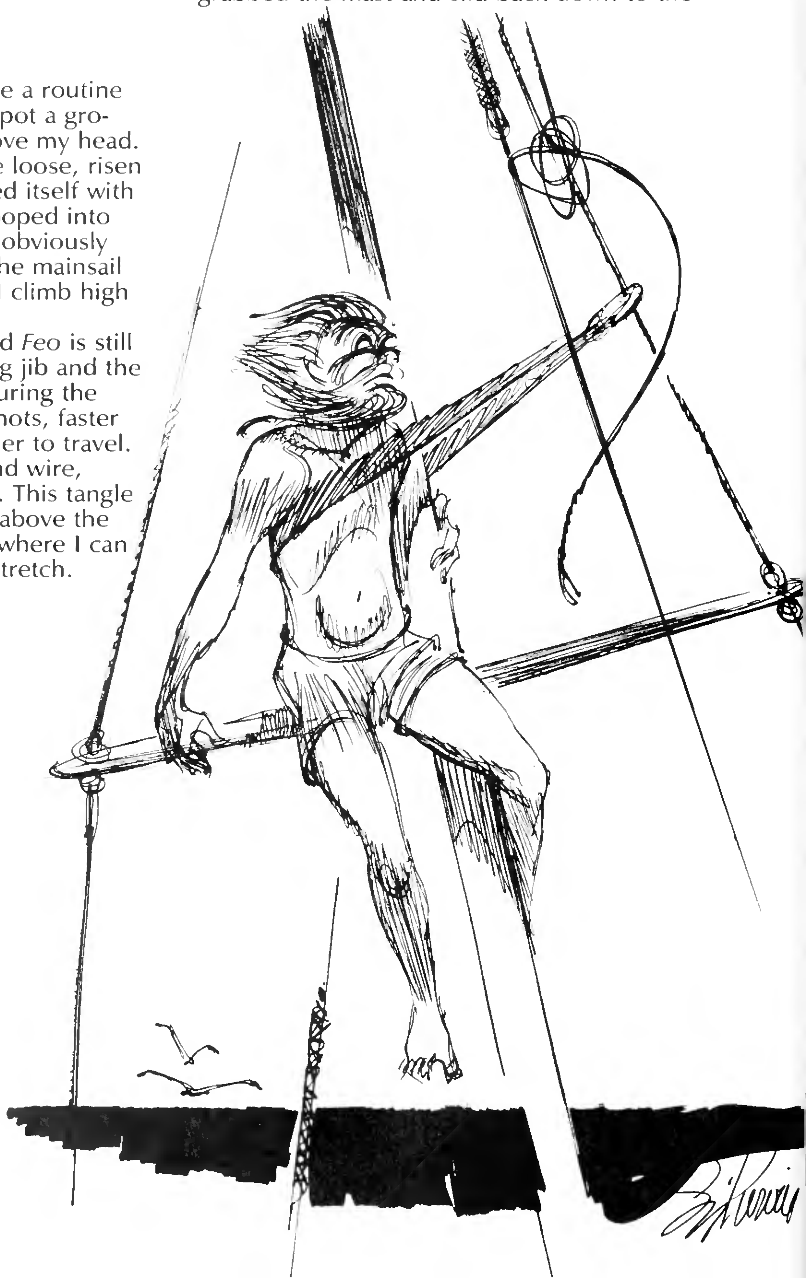
"The thing you fear is the thing you have to do anyway," says a voice. I realize it is my own, spoken into the wind.

I can ignore the problem for two more days in which the wind persists without slacking. My cabin table disappears beneath books on celestial navigation. They reassure me I cannot be lost at sea if I can calculate the moment the sun reaches its highest point in the sky. That noontime instant will tell me my latitude and longitude, and that is all I really need to know.

I run the engine for 40 minutes to recharge the batteries, and stare into the compartment to locate the source of pale smoke. I cannot find it. I can feel the diesel is running hot. What if I lose this source of battery power for all my lights and the loran? Somewhere behind me, in the burbling water tanks below the cabin floor, I hear an odd honking sound. I imagine it is the sound an ocean freighter makes in the instant before it runs you down.

By the next afternoon I have devised a way to go up after the rigging—a rope ladder of periodic loops in a heavy line hoisted up along the mast. I clip my harness to one heavy wire stay, which will connect me to the rigging as I climb, and step into the highest loop I can reach. Instantly a breaking wave rises under the boat and *Feo* pivots. The line slingshots me around the mast into the protruding metal winch for the mainsail, which nicks a small slice out of my right ankle above the bone.

Before the line can catapult me back I have grabbed the mast and slid back down to the



deck. I start to climb the lower wire stays to get to the crosstree but *Feo's* violent rolling shakes me loose in several attempts. The seas are just too rough now.

By the next afternoon the wind has fallen to about 15 knots and the seas are quieter. I have decided to climb the wire rigging by hand, hoist myself onto the crosstree and buckle myself to the mast with the safety harness. I have seen boatyard riggers clamber up between wires like these. Their method must be stored in my memory somewhere.

Suddenly, I am clinging by my fingers and braced legs to the lower stays, and have somehow hoisted myself onto the crosstree. The mast is cool and solid against my face, the crosstree braced under my thighs. I clip my harness and stand on tiptoe to discover I can reach the tangle. By attaching another line to it I can bring it to the deck to unravel.

The bowsprit leads us on, vibrant arrow to the southwest. I am suddenly intoxicated to be in this perch, alone, elevated by my own effort to a height I have always feared, staring now across the vacant ocean as *Feo* transmits a deep Pacific cadence through the mast into my bloodstream.

"This is why you came. This is what you came to find."

I still have another 1,600 miles to go.

The alarm above my head goes off with a high *beep-beep-beep* and jerks me awake as *Feo* pitches along in the darkness. The screen of the loran has gone blank.

I flip the indicator switch for the battery that runs the computer and all *Feo's* lights. The needle does not move.

The house batteries are dead. The automatic navigation is dead. The running lights atop the mast are out.

Feo can't be seen at night.

In a moment I have started the diesel engine, almost certain that it will fail again. It has choked itself off several times in the first few days out of San Francisco and I have not been able to find the problem.

Twenty minutes later, with a small charge back in the house batteries and the loran back on, the engine dies again. I don't dare restart it without finding the source of pale smoke that rises near the top of the engine, too hot to touch. It is nearly midnight.

By noon the next day, tools are strewn across the cabin floor. I am drenched with sweat from squeezing myself into the engine compartment and bracing myself against the roll and yaw of *Feo* running downwind.

Checking for air in the fuel lines, I have broken a crucial plug, spurting diesel oil into the bilge. I spend two hours with a hacksaw and file to make a new plug from an old bolt. All the incoming water and fuel lines seem to work. The engine finally restarts, but the outflow of sea water that normally cools the engine has stopped. Water is getting into the system but not passing through it.

I shut down the engine immediately. I suddenly see that salt water has been leaking out of the engine into the bilge from an obscured connection between the water pump and the engine block. Now I know why I had to pump so much yellowish water out of the bilge several days before.

I consider what I must do. Eat. Decide what it means to have no engine from here on. Get ready to take sights of the sun. With no engine, I can't sail up the narrow, reef-framed entrance channel into Honolulu, the only major harbor on Oahu for which I have brought a detailed chart. I now need a harbor I can sail into.

I try to imagine the next 1,400 miles and two weeks with no lights, invisible to anything that approaches me in the dark.

The lone brown seabird that has followed me day to day sits about 30 yards away, attentive, rising and falling with the waves. I do not assign it a gender because it has the qualities of an embodied spirit. What has brought it here? What does it see as it stares across at *Feo* and me?

I have been alone now for nine days, the longest solitude of my life. Nothing suggesting another human has even appeared on the horizon, yet I felt no loneliness or strain, busy with the tasks of keeping the boat and myself in order.

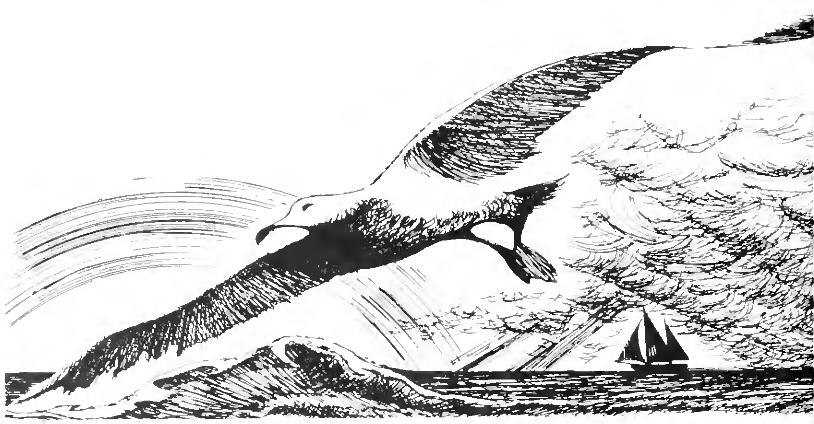
Becalmed now, the sails slat and the masttop wind vane spins against the sky. I am listening on a battery-powered tape to an aria from *La Bohème*, as the brown bird glides a whisper's breadth from the wave tops. It is searching for something, millennia of evolution collected in its perfectly arched wings. The bird and the water and the voices rise and fall in unison, as if answering the same conductor.

The Pacific is never without the sun or moon or stars or weather to complect her fully. Her clouds alone are knotted ropes, sweat-drenched bedclothes, boomerangs twisting, wild animals sitting tight against the approach of celestial hunters, biology's first contemplation of new patterns, silhouettes of every living thing that ever was or might come to be.

I have already found the content of some of my dreams and an end to some false imaginings—voices within and without that told me I could not, or should not, undertake this venture into the ocean and myself. All discovery means uncertainty, fear of error. The essence of not knowing is that we do not know what we do not know. This is the heart of letting go, and of becoming.

In a rare moment, the sun and moon hang west and southeast, distinct and free of clouds. I have studied the theory of finding my position in their intersection, but never put it to practice with the sextant's small mirrors and the printed celestial tables that connect man's time to the Earth's rotations. The simple act of bringing the sun and moon to the horizon, measuring their altitudes at a precise second of time recorded in

Greenwich, England, reduces their vast symmetries to two simple pencil lines on the chart. They put me at 30 degrees 40 minutes North latitude, 134 degrees, 39 minutes West longitude, 650 miles southwest of San Francisco. I am suddenly struck by how disengaged I had become from the physical world in which I have lived for almost 40 years.



Late in the afternoon, the sun performs alchemy on the horizon, burns black and purple clouds into liquid gold, pumps it across the waves in rivulets of orange light. High to the southeast, the moon has eluded the dark evening clouds and projects a silver path, which converges with the sun's brilliant stream. "Here you are," they proclaim: "Look—you are here."

In a few days, the Pacific high-pressure system has dropped its center of calm over this stretch of ocean. A relentless silence of windless water in motion rolls *Feo* side to side and redirects her despite any effort to steer. Sitting in the cockpit in this aimlessness, eating a sandwich and reading, I look up for no particular reason. What a warped fantasy to believe that a freighter is bearing down on me from about a mile away!

I have heard stories of freighters traveling for days with no lookout and their radar off. Perhaps, like me, they believe the chance of collision too remote to take seriously in thousands of miles of open water. I go below and return with a handheld bearing compass to check the direction of this illusion. It's approaching from 112 degrees. We are on a collision course.

I dive below for the two-way radio. Its transmission light flickers weakly as I call: "*Feo* to any freighter in the vicinity. Any freighter in the vicinity. Come in, please."

No answer. Was there enough power in the batteries to transmit a signal even a mile? The water pump for the engine is in pieces, and the breeze too faint to be felt. *Feo* lacks headway necessary to respond to the helm. We are dead in the water.

I clamber back up into the cockpit to check the freighter's bearing again—110 degrees. I wait one minute by my watch. Now it's 113 degrees. By now I can see the freighter's bow wave on both sides and the tall, imposing stem where it cleaves the water.

I would rather burn up the engine than be run down. I dive below again to start the engine, confident it will move me out of the freighter's path before quitting again. I have *Feo* in motion and turning back east when a voice crackles in the cabin.

"This is the *Bohini*. What do you want?"

My panic dissolves. Can he tell me his location?

"Just a minute." A silence follows and I switch off the engine before it overheats. Smoke wafts into the cabin.

"Thirty degrees, 39 minutes North, 135 degrees, 15 minutes West." (This is about 60 miles northeast of where I thought I was.)

By now *Bohini* has steamed alongside, a few hundred yards to the west.

"Thank you. Can you tell me if you had me on radar before I radioed you?"

The voice does not answer. There are no signs of life on *Bohini*'s deck as she crosses ahead of *Feo* by several hundred yards and continues north.

The great dead spot begins three days of drifting, rolling frustration. The sea is endlessly gray and smooth, an imitation sky. Overcast persists and I cannot see the sun for a sextant reading. Eventually I take the sails down to stop their incessant snap and bang, and simply drift. *Feo* behaves like a long red compass needle searching for a north pole that does not exist.

Seaborne trash becomes common. Plastic wrappers, bottles, small buoys adrift float alongside and stay there for hours, trapped in the Pacific calm. I imagine the wind never coming back. Do I have enough food and water? I develop a fetish about neatness in the cabin, and replay Bobby McFerrin's hit song, "Don't worry, be happy!"

The fear of freighters returns. What did it mean that two courses could cross so exactly in this vastness? How many small craft are run down out here and no one ever knows? (Think, says a voice—if it happened once, what are the chances it will happen again? You have to watch, you have to watch, says another.) Bobby McFerrin intercedes. "In every life expect some trouble; when you worry it makes it double. Don't worry."

I sense I have only started to discover just who is present when there is no one here but me.

Great, dark seas follow *Feo* now, breaking alongside and rushing onward to the southwest. Phosphorescent creatures in the water illuminate our path with pale green light. Charging downhill with a roar between waves, *Feo* pauses for a giant breath as the next sea rises beneath her stern, and collects herself for another swooping downward rush. I am

braced in the cockpit, hand hooked under the hatch handle, charioteer to this thundering creature let loose by the wind and herded uproariously down these dark and fiery slopes. I have lost track of time, of fear, even of myself.

In a few hours the wind has risen above 30 knots almost to a gale and I am anxious about the rigging. I have been spilling as much wind from the sails as I can, but I can't stay awake much longer, staring to the horizon for freighters that are not there. The seas loom well above my head and several have broken onto the deck. As I turn *Feo* up into them so I can wrestle the mainsail down, I sense that she is disappointed, unwilling to reduce her sails.

From inside the cabin before I collapse finally in sleep, I can watch vague seas tower toward us, shoulder *Feo* aside, and then collapse beneath her. I hear muffled conversation in the bilge.

"You," someone says.

"What?"

There is a loud thumping and stumping of feet. Voices are raised in long hallways, drowned by the sound of running water. Beneath me someone is bashing his head against a water pipe. I have calculated I have another 1,050 miles to go and wonder if I am showing any signs of fatigue.

By the end of two weeks I am convinced I can locate myself each day by capturing the high point of the sun at noon. A small cruising guidebook convinces me I can tack into the mouth of Hilo harbor and anchor in safety. *Feo* and I are now averaging about 145 miles a day in the northeasterly trade winds, with about 500 miles to go.

Without lights, I have trouble sleeping at night, seeing in every horizon twinkle a freighter's steaming light. I struggle daily with math errors that throw off the sextant results again and again. Just when I believe I am two days from Hilo, I can't get a sun sight to make any sense. I compute the numbers over and over. This was all supposed to be automatic by now! I could easily miscalculate my position by 30 miles or so and hit land in the middle of the night. I second-guess all my computations for the past two days and devise three alternative positions—all within 50 miles of each other, each producing a different course toward Hilo.

I sweat profusely, angry at the instruments and charts. They overwhelm my small table but refuse to give me certain answers. How do I know that I am approaching Hawaii? The island is so small in the Pacific, just 72 miles wide as I face it, Hilo the only anchorage on this side. What if I have been making the same mistake over and over in plotting my noon position by the sun? I could miss the island altogether.

I begin searching for a long cabin cushion that I can find nowhere on the boat, not even in the lockers and storage bins. I finally realize there is no such cushion, and never has been.

I decide to pick a course that is a compromise among the three positions I have conjured up on the chart. At 3:40 P.M. on the afternoon of my 20th day, I turn on the AM radio above deck and point it ahead.

Ukuleles!

An ad for Ralph's Burgers in Hilo is coming from someplace slightly to port, roughly where I believed it should be. Looking over my shoulder at gathering clouds, I see that I am followed by a rainbow. Several hours after darkness falls and six hours before I expect to see any signs of land, a green light appears directly ahead.

It is the heart of Hilo harbor itself, the marker light of the channel.

I am caught between elation and disbelief. I must be within 10 miles but don't dare venture into Hilo Bay under the threat of violent rain squalls that sweep the harbor at night and the certitude of freighter traffic to and from the islands' second busiest port. I decide to sail back out north for a few hours of sleep offshore before turning back to arrive at dawn.

Only when I wake up will I begin to realize what a serious error I have made.

I sit down on the battery box in front of the stove, clutch my chart of the Hawaiian chain, and stare at the small indentation at the big island's northern face that is Hilo.

I have missed it *again*.

After three weeks and 2,100 miles across the ocean I am on the threshold of Hawaii and I have to face a disheartening fact: *I can't get in against the trade winds.*

Feo is hobby-horsing slowly into seas that in several days of 30-knot breezes have built to the size of small tract homes, nearly four times the height of her deck. I brace myself at the stove to prepare food for another night and day—beans mixed with spaghetti sauce, a diced onion, noodles. I am soon spattered with the sauce, sticky with sweat, conscious of the mixture of smells in the galley. I have had no shower in the 22 days.

This island has only one northern face. I am leaving the western end and sailing north. Hilo *has* to be southeast. I have to sail far enough north again tonight to come back up across the trade winds. I have no choice.

Small cuts are appearing on my hands for the first time in the weeks since I set out. I am aware of new bruises on my arms and legs but have no idea how they got there.

I sense a palpable presence in the cabin and on deck. Someone or something is here, not corporeal but an accompaniment of spirit that might be religion or imagination or some expansion of myself I have not previously known.

What is this sensation and why is it happening now? Am I hallucinating, experiencing exhaustion as illusion? I have to go on deck suddenly to cool off from the tropically dense humidity of the cabin, closed off against seas that are breaking along the windward rail.

The clouds feed my confusion, making mountain ranges to the northeast where I know

there are none. I stare back south at the fading island, where in the chasms and ageless volcanic bluffs a line of chimpanzee heads has watched me come to the realization that I had been sailing in the wrong direction all afternoon.

By dawn *Feo* is nearly stationary in a gale, turned back once again from the flashing lights near Hilo's mouth, unable to work upwind against the procession of squalls that continuously sweep the coastline here. Charcoal clouds billow upwards into forbidding apparitions. The bow thrashes the oncoming seas, and the wind takes me further north from Hilo as the rolling water forces us gradually west.

The rain is pelting through amber light and the bowsprit beneath me leaps and dives like a carnival ride gone amok. Weightless in the plummeting downward rush to a trough, I crouch to take the jib off before the darkest, wind-laden clouds arrive.

Suddenly I am 14 again, fighting to get a jib down in a storm off Massachusetts. My father is at the helm of a friend's 36-foot racing sloop, grinning through the rain at me on the bowsprit, where I am doused by windblown seas. I can see he is pleased that I am not afraid, and depending on me to get this thing done quickly. Now, in this sudden trade wind squall, the seas off Hilo recall the motion and emotion of what passed between us that day so long ago, and a realization dawns:

In doing this thing I love, at last I see love most clearly, not just for my father but for myself. In the confluence of these memories and this moment, wind struck and enveloped in the night, I see that without such love there can be no real self.

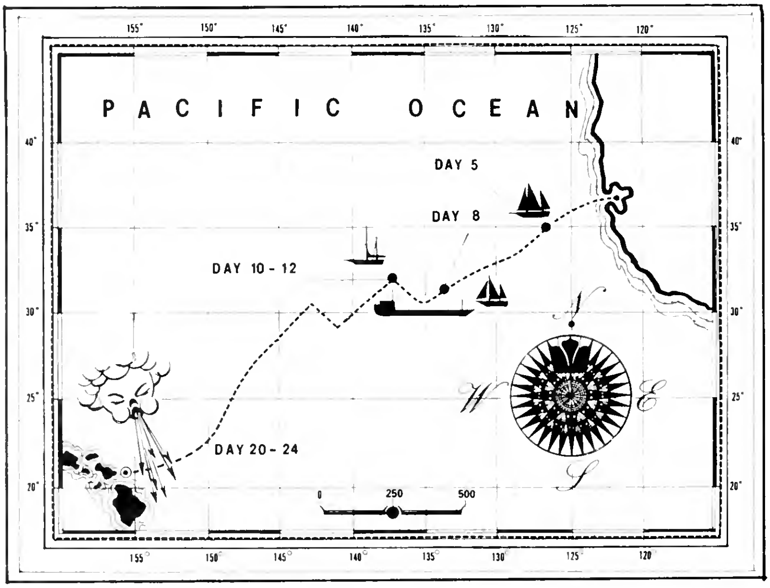
The rain and salt spray on my face are indistinguishable from sudden tears and I wonder if my father, 80 years old now and vacationing in a Maine coastal cottage, has felt anything in this instant of joy and discovery, transmitted from me across space and time.

In a few hours, *Feo* and I have turned back toward the island once again, straining to hold a course close to the wind. A gray and white petrel hovers as a plump and frantic sentinel flapping overhead. Flying fish whir from wave top to gully in frenzied flight, hummingbirds of the water. A sunlit forest fire burns in the ocean to the west, and more black smoke billows in from the northeast, pugnacious clouds in vague sunlight.

Steep rolling seas and scudding clouds in the early morning have made precise sextant shots impossible, but a series of midday sightings capture the sun at its highest point. This locates us 34 miles north of the harbor, about seven hours out. We can be there by nightfall, I figure, if we can just sail enough east of south.

But we cannot, pushed westward by the wind. I discover a 30-mile error in the sun sighting that means at least another 30 miles to go. If we are not lost, we are close to it, as I get three more sights of the sun in the afternoon that suggest Hilo will be nearly due south shortly after dawn. I am now afraid to believe my own calculations.

By dawn the rain has stopped, but the wind persists at nearly gale force under clearing skies. We are back within eyeshot of the shore, where a huge yellow farmhouse dead ahead pours steam from a chimney into the morning sky.



Oh my God. I was exactly here three days ago. I have made absolutely no progress since then.

The cockpit is a tangle of soggy lines, sails, and sailbags, signs of exhaustion that I have not put things back where they belong. I don't dare sleep for fear that I will hit some underwater volcanic abutment near shore that is not shown on my general chart. Whatever has held me so tenaciously away from Hilo—it must be more current than I realize—will not relent. Am I quitting if I change direction now? Do I need to summon the will to continue, or the wisdom to change course?

Feo's previous owners have left me dozens of charts of the South Seas that by chance include one of the western half of Lanai—the 14-square-mile island tucked under Molokai on the way to Oahu. The route there is a straight sail down the north face of Hawaii, west through the channel that separates it from Maui, around the

end of the U.S. Navy munitions island of Kahoolawe to a flashing white light on Lanai's southeastern tip—65 miles and roughly 12 hours away. Three and a-half miles farther along its western edge lies the circular harbor of Kamaulapau, roughly the diameter of a football field and, it appears, simple to sail into.

The trade winds have convinced me they are not to be fought, but joined. The little island is a straight run away from these seas and what has become the most powerful wind I have felt in the islands, now gusting above 35 knots. I do not know whether to expect in Lanai the squalls typical of Hilo, but the national ocean guide warns of sudden calms in the Kealakahihi channel on the approach. I will have to risk that.

The decision made, I turn downwind and *Feo* leaps ahead on the rushes of rolling sea that she has battled for so many days. I feel as though I am facing the edge of the world, aimed for a tiny hook to catch me before I plunge into oblivion. I picture *Feo* sailing into the tiny harbor at last, and try to hold the image.

We race on past the western tip of Hawaii, which tapers treeless to the water, toward a carved orange marble horizon. The seas are steel-muscled blue backs of ocean bison rushing to the falling sun, and Maui holds herself up to the north as a looming shadow, a frozen volcanic peak in the haze. In the distance along Maui's shore an ocean tug tows a flat barge a quarter mile astern, linked by an underwater cable.

"Pooshee! Pooshee!"

Porpoises explode off the stern, chasing *Feo* through the island mainstream, four fat black backs shining in curved unison. They startle me awake just as I am falling asleep on my feet in the cockpit, and I decide to give myself up to an hour's nap while the wind vane steers us downwind in open water and daylight.

After dark, I struggle to stay awake on chocolates and calisthenics. I am not alone, though perhaps no longer myself. The presence I felt before is back again, waiting in the cabin below, attentive on deck. It has no body; I can walk through the space it occupies.

By midnight we have rounded Kahoolawe and I stare across 15 miles of water to an amphitheater of lights. A bright white light flashing every 6.5 seconds, like the one that is supposed to mark the tip of Lanai, blinks out of the darkness. Have I found the right one or wandered to some other? I have to believe it's the right one. I adjust the wind vane to aim *Feo* toward it, and doze.

Feo is passing along a waterfront, a series of verandas. Figures move on porches, people are watching. There is no waterfront here in this open water, there are no people. Yet I see them in the darkness, standing where I know they are not.

The wind has begun to fall. By the time we close in on the flashing light, the breeze has died. Becalmed on another threshold, we drift, roofed by a panoply of stars. I no longer have the strength to stand or even sit.

I awake in a pile of sails in the cockpit at dawn. A dent in the cliffs flanked by white steel oil drums, Kamaulapau sits 3 miles across the flat water to the west. A breeze so light it barely ripples the water plays first across Lanai's sweltering stone bluffs from the east, then from the empty Pacific to the south. My nail-bitten fingers grow saltsore on the wheel, which I must tend every moment to make any headway toward the harbor. The sun climbs up my back, tropical heat without relief rising toward noon.

In midmorning desperation, I hatch a plan to push us the last few yards to shore. I will take the dinghy off the deck, lash it to *Feo*'s stern, attach the tiny outboard motor and drive *Feo*'s engineless bulk into the harbor. I soon have the dinghy in the water, taking care not to drop the line, when some mysterious force strips it from my fingers and casts it into the water.

I have lost the dinghy overboard in flat calm! I rush aft, a voice shouting: "Don't fall overboard, don't fall overboard!" Over the lifelines and down onto the selfsteering apparatus I climb to stretch my hand toward the passing rope.

It is out of reach, gone, adrift. I have lost control.

In moments the calamity has reversed itself. A fishing boat has appeared a few hundred yards astern and the skipper responds to my whistle. As he brings the dinghy alongside, his crew grinning, I hand one of them an untouched bottle of Scotch I had been given for emergencies.

In three more hours, *Feo* has inched within a few hundred yards of the tall green buoy at Kamaulapau's mouth. My head is baked, my hands swollen immobile. I recall from my childhood the breezes that sprung up when we approached the mooring in Maine. My mother called them "anchorbreezes."

I look to the sky and realize I have come to believe in the power of the heavens, the movement of spirits on wings.

"I could use an anchorbreeze now, wherever you are," I say. "I know you're thinking of me. I really need it. Now."

The wind darkens the water just after this moment and moves *Feo* gently past the last buoy. She finds the center of the harbor and I release the anchor from the bowsprit. The heavy chain links roar in rusty pursuit of the anchor into 50 feet of water, and all motion ceases.

We have come to Hawaii, together, alone. □

letters

To the Editor:

Congratulations for an exciting and informative issue about *Alvin* et alia. And, of course, to hear the views of old friends—Allyn, Holger, J. Fred, Chupe, Ballard and Henry C.—is most refreshing. Professor Weissmann's essay is particularly poignant. Perhaps the article exhibiting the most potential is that of Cindy Lee Van Dover. Whoever is her tutorial advisor must be wondering by this time, "Who is teaching whom?" Would that it could ever be so.

Dean F. Bumpus
WHOI Scientist Emeritus
Brownfield, Maine

To the Editor:

Upon reading the Winter 1988/89 issue of *Oceanus* commemorating the 25th birthday of *DSV Alvin*, I was struck by the almost complete lack of acknowledgment of the crucial roles of engineers on the staff of the Woods Hole Oceanographic Institution (WHOI) in the birth and continuing life of *Alvin*. Their contributions include the design and construction of *Alvin* as an instrument platform and as a safe conveyer of people into the deep sea. They created the instruments and ancillary systems that make *Alvin* useful as a part of science. And they conducted original research on the behavior of materials and structures in the ocean environment and original system designs on the cutting edge of technology.

James W. Mavor, Jr.
Former WHOI Engineer and Naval Architect
Woods Hole, Massachusetts

EDITOR'S REPLY: There was no intention whatsoever to slight the important role of engineers in the development and success of *Alvin*. Indeed, even if it wasn't explicitly stated, our anniversary issue was very much a tribute not only to the submersible itself but, in large degree, to the engineering and technological talent that created *Alvin*.

To the Editor:

Upon reading the article "A Quarter-Century Under the Sea" (*Oceanus*, Volume 31, Number 4, pp. 2–9), I came across an error in the second paragraph, which states ". . .the mid-ocean ridges, where new continental material is birthed from deep within the earth." New continental material, as we think of it, is not extruded from the mid-ocean ridges. According to the theory of plate tectonics, oceanic crustal (basaltic) magma is extruded along the mid-ocean ridges.

New continental crust comes from the subduction and melting of basaltic oceanic crust under the continental margins, eventually erupting at the surface from explosive volcanos, such as Mt. St. Helens, in the forms of andesite, ash, and possibly some granite depending on the amount of surrounding metamorphism. Basalt, however, does not come from these volcanos. It comes from plate boundaries and isolated hot spots on the ocean floor.

A more proper statement would be to substitute the word "crustal" for "continental" in the article.

R. David Hartshorn
Senior, Biology Major
George Mason University
Fairfax, Virginia

To the Editor:

While *Oceanus* Volume 31, Number 2 is a commendable survey of subjects on the Antarctic, it was a great surprise to me that it omitted any and all reference to Antarctic and subantarctic birds. Clearly, birds are one of the top predators in the Antarctic and one of the key elements of the ecosystem.

I wonder if you were unfamiliar with the rather vast body of literature on Antarctic birds. If so, you might be interested in a publication now almost complete by J. Cooper and D. Pillay called *Publications and Theses on Antarctic and Subantarctic Birds, 1988*. Cooper already published a list of these for 1987 in the journal *Cormorant*, Volume 15. At that time, there were 89 scientific publications on these birds alone. You might also wish to refer to the *Penguins of the World* bibliography compiled by A. J. Williams, J. Cooper, I. P. Newton, C. M. Phillips, and B. P. Watkins.

I hope that in some future issue of *Oceanus* you will consider rectifying this omission. Avian research has contributed much to the understanding, public awareness, and protection of the Antarctic ecosystem.

Laurie A. Wayburn
Executive Director
Point Reyes Bird Observatory
Stinson Beach, California

To the Editor:

Re the article, "The Halcyon Days of Sea Grant" (*Oceanus*, Volume 31, Number 3) and specifically the author identification at the bottom of page 4:

While I had the pleasure of working closely with South Carolina Sea Grant years ago during my employment with the Federal Sea Grant office, I was never on the SC Sea Grant payroll. Apparently, someone is impersonating me, probably hoping to dine on Carolina prawns.

Please list me as happily and productively retired.

Harold L. Goodwin
Bethesda, Maryland

EDITOR'S REPLY: For the record, Harold L. Goodwin, co-author of "Halcyon Days," is former Deputy Director of the National Sea Grant Program. During his long and distinguished career, he was also a journalist, a member of the Marine Corps, and an official with the National Aeronautics and Space Administration, among other things. Our apologies for misidentifying him.

book reviews

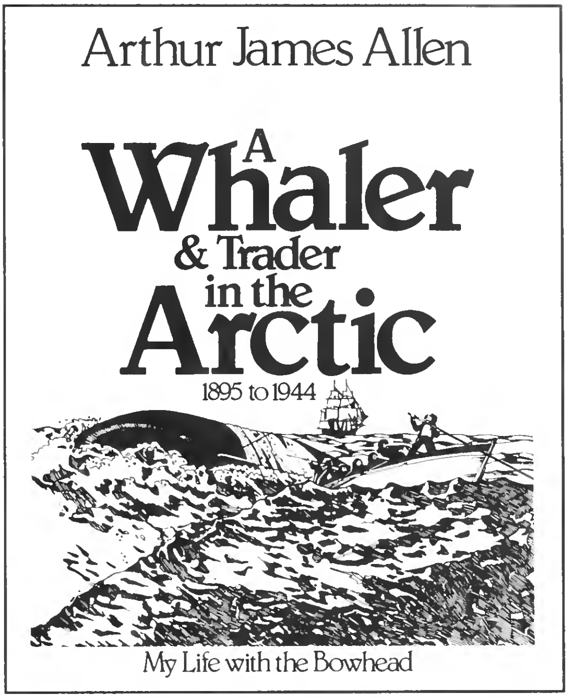
A Whaler & Trader in the Arctic by Arthur James Allen. 1988. Alaska Northwest Publishing Company, Anchorage, AL. 213 pp. $9.95. Paperback.

In the 1890s a strapping youngster from San Francisco, still in his teens, left home to work aboard the whalers in the Arctic. Unlike most of his shipmates, Big Jim Allen fell in love with the bleak, icebound country and soon decided to carve out a life there. In the scornful phrase of the time, he "went native."

To support himself and his new Eskimo wife, Allen turned to hunting whales in the native style. Going out from shore with his Eskimo crews in sealskin canoes called umiaks, he prowled amid the broken ice for bowheads. So successful was he in his new surroundings that he eventually became something of a legend, even in the "big outside," a great white hunter of the north. On several occasions, Hollywood sent crews up to film him in action.

Even so, Allen, who died in 1944 at the age of 69, would probably be forgotten today, except for this remarkable memoir. In the late 1930s he began writing letters to a daughter in San Francisco about his early life in the Arctic. For many years, these old papers remained undiscovered in the hands of his family. Then about a decade ago, another daughter recognized what precious documents they were and assembled them into a book recalling a ruggedly innocent world fast fading from memory. Unfortunately, her father's posthumous autobiography quickly slipped into publishing oblivion.

Now the Allen saga has been reprinted in a handsome new paperback edition, which may finally get it the wider audience it deserves. Allen is a superb storyteller. As you read his reminiscences, you can almost hear him holding forth before the crackle of a warm fire in an Arctic cabin on a cold winter night. His yarns are filled with barrels of action and peopled with both heroes and villains. He is especially lively when he describes the pursuit of the whales.



A Test of Men and Ships

Allen begins with his experiences aboard the commercial whalers that first took him north just before the new century. Typically, the ships spent three years at sea in order to make the voyages pay off. (Often they did not because of a poor catch or falling prices.) The trips were a test of men and ships, which were locked in the Arctic ice for the long, dark months of winter. One reason the ships remained north was so they could go after the whales as soon as the ice started breaking up. When spring finally arrived, the hunt for bowheads began.

In contrast to the Eskimos, who valued the whales as food, the white whalers were mainly interested in whalebone, or, more accurately, baleen: the forest of flexible, keratinous plates that hang from the upper jaw of whales of the suborder Mysticeti. The whale uses them as a sieve to strain food, mostly plankton, out of the sea. Individual strips of baleen can run up to 13 feet in length. They are tough and whiplike. In the days before spring steel, they made excellent corset stays and had other commercial uses as well. Bowheads have more baleen than other whales, and so were the preferred target of commercial whalers. A single bowhead could produce as many as 600 plates, bringing many thousands of dollars, a hefty sum in Allen's day.

The crews who hunted the whales were a boisterous, brawling, hard-drinking lot. Big Jim managed to avoid fights, perhaps because at six feet plus he was too imposing a figure to challenge. But he makes it plain why Arctic whaling attracted such an unruly crowd: the work was dangerous and shipwrecks occurred all too frequently. Many of the vessels were schooners equipped only with small auxiliary engines. These ships were easily smashed by the ice if they were carelessly positioned or caught in a storm.

The whaling fleet would winter off Herschel Island in the Beaufort Sea, just over the Canadian border. The canvas sails were used to make a shelter on deck—the so-called bull room where the carpenter would set up shop and build dog sleds. The engine had to be turned over daily by hand to make sure the propeller was free and the ice was regularly chopped away from the rudder to keep it from being crushed.

Eskimos celebrating the conclusion of a successful whaling season at Barrow, Alaska, circa 1898. Note the festive blanket-tossing of one of the whalers in background. From A Whaler & Trader in the Arctic. *(Courtesy Special Collections, University of Washington Libraries)*

In the winter of 1895–96, Allen writes, some six hundred sailors on 13 ships were holed up at Herschel Island. They hunted caribou with the help of native guides, staged theatricals and played baseball on the ice to amuse themselves, and bought whatever goodies might be available at the ship's store—"the slop chest." The purchases were assessed against their pay, which came in the form of "lays," or shares of the ship's catch. By the end of a voyage, many a bored sailor might have squandered away all his pay on frivolous purchases.

Desertions were common. Allen recalls that some 15 crewmen, having heard stories of the gold find in the Klondike, stole off one night with sleds, dogs, and a store of food to seek their fortunes in the gold country. Most were never heard from again.

In April, as the ice cracked, the hunt commenced. Each ship had six or seven whaleboats. They were about 30 feet long and seven feet wide. In addition to harpoons, lines, and other whaling gear, they carried a 22-foot steering oar, a mast and sail, a compass, and a lantern, as well as enough food and water to stay out for several days.

Spooked by a Noisy Oar

As soon as the lookout spotted the V-shaped spray of a bowhead, the whaleboats were lowered over the side with two men in the boat and four manning the davits. The four would slide down the lines after the boat was launched. The mast and sail would quickly be raised—even the noise of an oar in the water might spook the whale—and the boat would head off to the area where the bowhead was expected to surface. The captain remained on board the mother ship, though sometimes he would follow after the whaleboats to observe the action—much to the distress of the whalers. During one season, Big Jim's ship didn't catch a single whale because, he reports, the captain turned on the engine to keep up with the whaleboats and invariably drove off the whales.

A whale was attacked with a darting gun. It launched a harpoon to which a bomb and line were attached. The bomb exploded on impact. If the first shot didn't kill the whale, a second would be fired. The whale might also be struck with spears and long knives. If the whale threatened to pull the boat under, the crew would reluctantly cut it free. Sometimes a whale might upend the boat, spilling the crew into the icy water. If you were wearing heavy, long-legged rubber boots instead of the fur ones favored by the Eskimos, they'd quickly fill up with water and you'd be pulled under.

Once the whale was killed, a flag would be planted in it so that it could be spotted later and a hole was cut into the tail for towing. As Allen writes, this wasn't work for "cheechakos"—the Eskimos' word for greenhorns. Allen himself was no cheechako: he got a whale on the very first try. American whalers continued to hunt bowheads in the Arctic until the 1920s, when the enterprise finally became uneconomical because of the diminished demand for baleen.

The Eskimos, however, have continued to hunt them. Then as now, whaling was very much a communal affair, a central part of Eskimo life for both the sustenance it offered and the spiritual value of the hunt. The skins for umiaks were sewn by the women of the village. These skilled seamstresses also made "pokes," or sealskin floats, which were attached like buoys to the whales to keep them from diving.

Whaling among the Eskimos also started at the end of April, when the northeast winds began blowing the ice off shore, creating floes. In preparation, the crews would cut roads to the water, so that the umiaks could be hauled there by special sleds, along with the darting guns and other paraphernalia. By Allen's day, the Eskimos were already using much the same equipment as the white men. Although they also concentrated on bowheads, they might occasionally take a beluga, which could be killed with an ordinary rifle. The Eskimos kept the meat but bartered baleen for supplies from white traders.

Locating whales was an art. Skilled native whalers would look for certain types of rough ice that the whales would roll under and use to scratch whale lice—actually small crustaceans—off their skin.

Superstition played a role in the hunt. It was considered bad luck to whale after shore birds began laying their eggs. Illustrious ancestors had to be honored. When the whaling was over, pieces of "muktuk"—blubber—were placed on the graves of whale hunters who had made at least three kills.

Once a whale was taken, a fast runner was sent back to the village and presented a piece of muktuk to the boatheader's wife as a token of the crew's good fortune. She would paint black marks on her face, and would go out to the end of the road where the dead whale had been hauled up. Her man would also blacken his face, painting a little whale's tail on either side of his mouth. Then she would cut a little piece of skin from the whale's snout, perhaps say a prayer, and offer the whale a ceremonial drink of water.

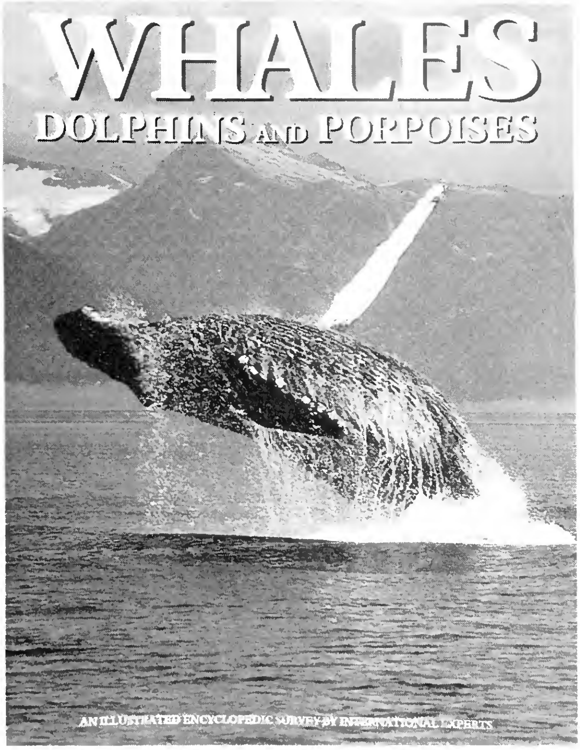
Days of Celebration

The whole village would be on hand for this joyous occasion with everyone sharing in the muktuk. Blubber from the first whale of the season was considered a special treat. The butchering would be accompanied by several days of celebration, with singing, dancing, and storytelling. A highlight of these festivities was the blanket-tossing, during which the successful whalers, starting with the captain or his wife, were launched high into the air by other villagers with a "nalukatak," two large walrus skins stitched together to form a kind of trampoline.

There was, of course, more to Allen's life in the Arctic than whaling. He hunted seals and polar bears. He made dangerous winter treks across the ice, during which igloos were hastily raised as protection against storms. He also seems to have been a shrewd trader. With controlled sorrow, he describes the drowning of his son. Unlike many whites of his era, Allen is a surprisingly sympathetic observer of the Eskimo character, tolerant of such practices as the exchange of wives and babies. He recalls, for example, an Eskimo mother with many children who was asked by a childless white school teacher if she might adopt her next baby. No, replied the Eskimo woman, but she would lend her husband.

For all his gifts as a troubadour of the north, however, Allen will never be mistaken for a Jack London or Robert Service. His prose is as rough-hewn as the life he describes; he leaves out critical details at times and hops back and forth over the years with confusing abandon. Still, he has a keen eye and a sharp wit, and an ingratiating way of spinning a yarn. He portrays his vanished world with a candor and freshness that bring it poignantly back to life. That may not be enough to qualify him for a poet's laurel but it surely merits a few hefty slices of muktuk on his grave.

Frederic Golden
Acting Editor
Oceanus



Whales, Dolphins and Porpoises **edited by Richard Harrison and Michael M. Bryden. 1988. Facts on File, Inc. New York, NY. 240 pp. $35.00.**

A sobering thought: there are now probably more books about whales than there are right whales in the North Atlantic. Since whales first became symbols of the environmental movement, there has been a seemingly endless line of books about whale biology, whale identification, whaling history, whale art, and even—heaven help us!—whale mysticism.

These books vary considerably, from excellent to frankly abominable. More than one has perpetuated ideas that research has long since confounded, or carelessly used fictive notions to fill gaps in our understanding of these enigmatic mammals.

It's therefore a pleasure to welcome this excellent compendium, edited by Sir Richard Harrison, a distinguished Cambridge University anatomist, and Michael M. Bryden, an Australian marine mammal biologist with wide field experience. *Whales, Dolphins and Porpoises* comes perhaps closer than any of its rivals to a seemingly impossible dream: it combines a wealth of accurate information with a feast of spectacular photographs. As a handsome addition to the coffee table, it will evoke satisfying "oohs" and "aahs," and as a comprehensive introduction to the biology and behavior of cetaceans, it will help the college student with his next essay.

The first of the three sections, entitled "Whales of the World," deals with the evolution, taxonomy, and distributional ecology of cetaceans. It includes what is, in effect, a field guide to various species, accompanied by illustrations that are, if not perfect, at least tolerably realistic. The second section, "The World of the

Whale," contains more detailed information on biology and behavior. As with the rest of the book, each subsection is written by an authority on the topic in question. The final section, "Whales and People," provides the counterpoint to its more didactic predecessors, and offers a history of whaling, a review of whales in art and literature, and articles on captivity, strandings, and "human contact." Books that attempt to combine a scientific perspective with more literary musings often result in an unsuccessful marriage of the two, yet this one succeeds. It's not at all jarring to find a reproduction of the famous dolphin fresco from the Minoan palace of Knossos just a few pages beyond a review of the social behavior of baleen whales.

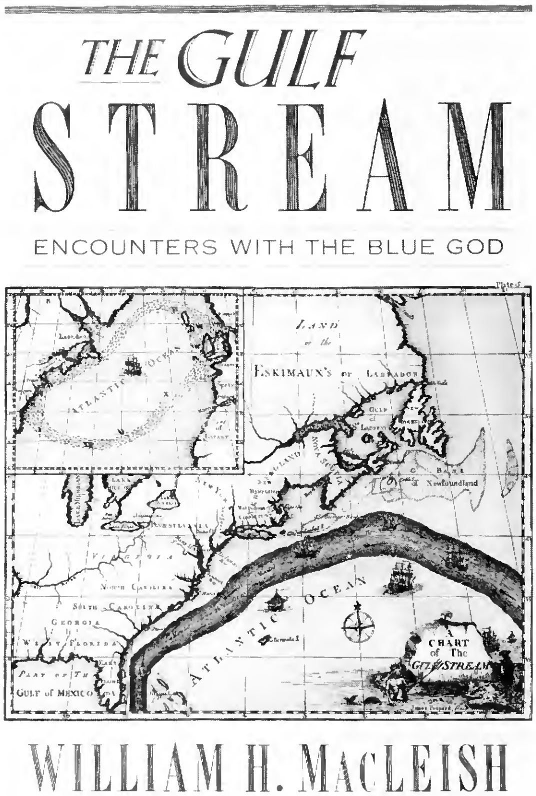
As one would expect in a work that attempts to distill knowledge from so many sources in a rapidly expanding field, the book isn't devoid of errors. We're told, for example, that fin whales "avoid. . . coastal waters," which comes as a surprise to those of us who regularly watch them from the beaches of Cape Cod or Long Island. And a caption says that whale mothers have an "aunt" in "constant attendance for protection" of the calf. While this is true of certain toothed whales, the notion has long since been discredited for baleen whales; among humpbacks, for instance, the "aunts" have turned out to be mature males that are probably waiting for an opportunity to mate with the mother.

There are also some errors of omission. Given that a great deal of our present understanding of whales comes from long-term studies based on the recognition of individual animals—by the markings on their backs or the shapes of their flukes—one would think this topic deserved an entire article instead of incidental mention. And the article on strandings leans far too heavily on a single hypothesis: the idea of the article's author, Margaret Klinowska of Cambridge University, that they result from a disorientation of the biomagnetic navigation system possibly possessed by certain cetaceans. While's there's some interesting evidence to support her theory, it's far from widely accepted, and other researchers have equally convincing data for alternative explanations.

But my major objection is to the article on captive cetaceans. One doesn't have to read the biographies of the contributors to discern that the author, Victor Manton, makes his living displaying cetaceans (as curator of Britain's Whipsnade Park). The article reads like a press release, lavishly praising the contributions made by oceanariums to public education and scientific research, yet glossing over or ignoring concerns about the well-being of captive show animals. At points, the article becomes frankly insulting, as when Manton contends that performing dolphins are "generally extroverted animals that respond to applause or public enthusiasm."

These shortcomings notwithstanding, the editors deserve high marks for their conservative, well-researched approach: if science is largely ignorant about a topic, they say so, and don't attempt to fill up their pages with meaningless guesses based on skimpy data. Overall, they've produced an excellent book that stands out among the gathering crowd of whale publications and will be turned to repeatedly for instruction or simply enjoyment.

Phillip J. Clapham
Director, Cetacean Research Program
Center for Coastal Studies
Provincetown, Massachusetts



The Gulf Stream: Encounters with the Blue God **by William H. MacLeish. 1989. Houghton Mifflin Company, Boston, MA. 233 pp. $19.95.**

It sweeps northward along the American coast until Cape Hatteras, warming the shore with its tropical waters, then veers out to sea. Along the way it carries an abundance of marine life—from lowly jellyfish to top-of-the-food-chain predators like tuna. It provides a welcome boost in speed for shrewd skippers who know how to make use of it, and, conversely, imperils southbound coastal voyagers who ignore it. The pioneering 19th-century oceanographer Matthew F. Maury poetically called it "a river in the ocean," but, as author William H. MacLeish reminds us in this delightful book, the Gulf Stream isn't really a river or stream at all.

It is part of a great gyre, or whirl, of salt water, created in part by the Earth's spin, that loops the North Atlantic in a giant ellipse. Even after a century of scientific investigation, the myriad effects of this system, as powerful as its currents may be, still remain elusive. We don't know, for example, if it really brings tropical heat to an otherwise chilly Europe, as myth has it, or understand very much about the dynamics of its smaller eddies—the rings within the great ring that can trap an errant sea turtle or speed along a delighted yachtsman—or fully appreciate the role of the opposing currents at work far below those on the surface.

But for all their questions about the Blue God, as MacLeish calls the stream, a play on T. S. Eliot's name for the Mississippi River ("A strong brown god—sullen, untamed and intractable"), scientists are beginning to close in on it. In his book—really a series of interrelated essays, all of them nontechnical in language without an equation among them—MacLeish provides us with an elegantly written, fast-paced, and up-to-date introduction to what is known, and not known, about the Gulf Stream system.

Of one thing, MacLeish and his experts are sure: Beyond helping to maintain the planet's heat balance, the stream has played a surprisingly large role in shaping our history. The Pilgrims landed on Cape Cod rather than in Virginia because the current drove the *Mayflower* north. After the stream (or, more precisely, the portion now called the Florida Current) was discovered by Ponce de León's pilot during the search for the Fountain of Youth, the conquistadors used it to establish their infamous gold route—the Carrera de Indias—to carry home their plunders. The Spaniards tried hard to keep this knowledge secret, going so far as to throw overboard their sailing instructions if they were threatened with capture.

But the word gradually got out, especially among Yankee fishermen. When Ben Franklin asked his cousin Thomas Folger, a Nantucket whaling captain, why the English trans-Atlantic mail packets were so much slower than the American ships, Folger provided him with the answer. That information enabled the canny diplomat-scientist, who made eight Atlantic crossings during his long lifetime—and took the water's temperature on most of them—to publish the first reasonably accurate maps of the stream. Indeed, in some histories, he gets credit for identifying it. (The lost first version of the famous Franklin-Folger chart was rediscovered by Woods Hole oceanographer Phil Richardson in a Paris archive a decade ago.)

Actually, the "sea beans" that occasionally washed ashore in Ireland and Scotland had long hinted of the existence of a trans-Atlantic current. Some people said they were the seeds of trees growing under the sea. Others speculated they had floated all the way from the Spice Islands; hence the name Molucca beans. In 1696, the British botanist Hans Sloan finally settled the argument by identifying the strange seeds as the offspring of plants he knew grew far across the sea in Jamaica.

The Sailors' Current

As much as it was an aid to shipping in the age of sail, the stream also posed dangers. On southerly runs, coastal traders had to stay far inland, risking shoals and rocks, to avoid the stream's countervailing current, which can run as high as four or five knots. Before it became generally known as the Gulf Stream in the 19th century, it was called, for a time, the Sailors' Current.

MacLeish, who edited this magazine for a decade, isn't satisfied just to recall the stream's history. He sails the Blue God himself. On one of his voyages, he rides the bridge of a huge, highly automated chemical carrier on the run between Baton Rouge and New York. Even for this 635-foot diesel-powered behemoth, the stream can make a difference. By deftly steering to take advantage of the current, the skilled young captain can save a third of a day in sailing time and some $10,000 in fuel. On another voyage, MacLeish is the guest of the Coast Guard aboard its 210-foot cutter *Dauntless*, assigned to sweep the Yucatán Channel for drug smugglers. In the very same waters in which the old Spaniards began their booty-laden journeys home, *Dauntless* seizes a little craft carrying some 10 tons of marijuana.

The most dramatic of MacLeish's passages is aboard the 45-foot schooner *Welcome*, a replica of an 1815 revenue cutter, owned by a friend, the New England yachtsman Art Snyder. *Welcome* follows the route of Columbus' first voyage along the great gyre's southerly arc, weighing anchor in Portugal, stopping off in the Canary Islands, and then catching winds and current for the Caribbean. MacLeish keeps the Admiral of the Ocean Sea's journal at his side. And as he feasts grandly on chicken tandoori aboard *Welcome*, he can't help but think of the wine going sour and the biscuits and cheese turning stale and mutiny in the air aboard Columbus' little flotilla. Still, in spite of the primitive conditions aboard them, *Niña, Pinta*, and *Santa Maria* easily outsail the smaller *Welcome* to the "Indies."

There's a lot more to MacLeish's literary wanderings in the stream. He dives in the Bahama Banks for salp, sharing the water with nosey sharks, and fishes off Massachusetts for bluefin tuna. He goes on an ice patrol aboard a Coast Guard C-130 Hercules patrol craft off Newfoundland and rides a giant container ship from New Brunswick to England. He listens to veteran oceanographers like Henry Stommel talk of the days when his complex science was more intuition than high-speed calculations, and visits with modelers like Harvard's Allan Robinson who use supercomputers in their efforts to predict the stream's fickle whirls and flows.

As he takes us on his grand tour of the great gyre, MacLeish, a son of poet-playwright Archibald MacLeish, is a superb guide. At moments he is Hemingwayesque, though without the bravado. At other times he is the patient teacher, trying mightily to explain a challenging science in a flow of poetic imagery. Above all, he is a splendid shipmate, finding life and adventure in what a cynic might say is no god, only water. —**FG**

Errata

Oceanus Vol. 31, No. 4, Winter 1988/89
DSV Alvin: 25 Years of Discovery

On page 7, because of a printer's error in some copies, several lines were omitted in a sentence that should have read: The crew rides in a small steel or titanium sphere, capable of withstanding enormous pressures, while most of the mechanical components are hitched onto a so-called exostructure, a framework external to the hull. Lacking the protection of an enclosing compartment, each component on the exostructure must be able to withstand the pressure on its own. In *Alvin,* as with other submersibles, a smooth plastic skin or fairing surrounds the exostructure.

On page 42, because of an editing error, the closest relatives to all deep-sea vent organisms were incorrectly given as Paleozic limpets. The sentence should read: The nearest relatives of such species as the several families of limpets are known from the Paleozoic period, more than 250 million years ago.

On page 46, the footnote defines surface mesoscale eddies instead of deep-sea vent mesoscale eddies, which are eddies tens of kilometers in diameter rather than hundreds of kilometers.

Books Received

Biology

Animal Navigation by Talbot Waterman. 1989. Scientific American Books, New York, NY 10010. 243 pp. + x. $32.95.

Aspects of Decapod Crustacean Biology edited by A. A. Fincham and P. S. Rainbow. 1988. Oxford University Press, New York, NY 10016. 375 pp. + xv. $98.00.

Biology and Mechanics of the Wave-Swept Environment by Mark W. Denny. 1988. Princeton University Press, Princeton, NJ 08450. 329 pp. + xiv. $60.00.

Body and Brain: A Trophic Theory of Neural Connections by Dale Purves. 1988. Harvard University Press, Cambridge, MA 02138. 231 pp. $35.00.

Fish Viruses and Fish Viral Diseases by Ken Wolf. 1988. Cornell University Press, Ithaca, NY 14850. 476 pp. + xii. $57.50.

Introduction to the Study of Meiofauna edited by Robert P. Higgins and Hjalmar Thiel. 1988. Smithsonian Institution Press, Washington, D.C. 20560. 488 pp. $39.95.

Man in the Antarctic edited by J. Rivolier, R. Goldsmith, D. J. Lugg, and A. J. W. Taylor. 1988. Taylor and Francis, Philadelphia, PA 19106. 223 pp. + xxv. $58.00.

Modern Planktonic Foraminifera by Ch. Hemleben, M. Spindler, and O. R. Anderson. 1989. Springer-Verlag, Secaucus, NJ 07094. 363 pp. +xiv. $98.00.

Culture of Science

The Concepts of Science: From Newton to Einstein by Lloyd Motz and Jefferson Hane Weaver. 1988. Plenum Press, New York, NY 10013. 435 pp. + x. $23.50.

The History of Science and Technology: A Narrative Chronolgy, Volumes 1 and 2 edited by Edgardo Marcorini. 1988. Facts on File, New York, NY 10016. 889 pp. $160.00.

Scientific Management, Socialist Discipline, and Soviet Power by Mark Beissinger. 1988. Harvard University Press, Cambridge, MA 02138. 363 pp. + xii. $30.00.

Earth Science

The Archaeology of Prehistoric Coastlines edited by Geoff Bailey and John Parkington. 1988. Cambridge University Press, New Rochelle, NY 10801. 154 pp. $42.50.

The Ocean Basins and Margins, Volume 7B: The Pacific Ocean edited by Alan E. M. Nairn, Francis G. Stehli, and Seiya Uyeda. 1988. Plenum Press, New York, NY 10013. 642 pp. + xiv. $95.00.

The Theory of Earth Science by Wolf von Engelhardt and Jörg Zimmerman, translated by Lenore Fischer. 1988. Cambridge University Press, New Rochelle, NY 10801. 381 pp. + xiii. $75.00.

Thermal History of Sedimentary Basins: Methods and Case Histories edited by N. D. Naeser and T. H. McCulloh. 1989. Springer-Verlag, Secaucus, NJ 07094. 319 pp. + xiv. $64.00.

Environment

A Citizens Guide to Plastics in The Ocean: More Than a Litter Problem edited by Kathryn J. O'Hara, Suzanne Iudicello, and Rose Bierce. 1988. Center for Environmental Education, Washington, D.C. 20036. 131 pp. Free.

Managing American Wildlife: A History of the International Association of Fish and Wildlife Agencies by Dian Olson Belanger. 1988. University of Massachusetts Press, Amherst, MA 01004. 247 pp. + xv. $11.95.

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The Demand for Atlantic Salmon in Canada: Issues of Functional Form and Parameter Stability by Biing-Hwan Lin. 1988. Alaska Sea Grant College Program, Fairbanks, AK 99775. 19 pp. $2.00.

An Econometric Analysis of Atlantic Salmon Markets in the United States and France by Biing-Hwan Lin and Mark Herrman. 1988. Alaska Sea Grant College Program, Fairbanks, AK 99775. 19 pp. $2.00.

Fishery Science and Management edited by Warren S. Wooster. 1988. Springer-Verlag, Secaucus, NJ 07094. 339 pp. + vii. $49.50.

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Proceedings of the Fourth Aquaculture Conference edited by Sue Keller. 1988. Alaska Sea Grant College Program, Fairbanks, AK 99775. 236 pp. + iv. $10.00.

The Provident Sea by D. H. Cushing. 1988. Cambridge University Press, New Rochelle, NY 10801. 329 pp. + x. $65.00.

General Reading

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Physical Science

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Ships and Sailing

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Building the Blackfish by Dana Story. 1988. Ten Pound Island Book Company, Gloucester, MA 01930. 173 pp. + xii. $24.95.

Nautical Quarterly: Number 44 Winter 1988. Nautical Quarterly Company, Essex, CT 06426. 120 pp. $16.00.

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The Skin Boats of Saint Lawrence Island, Alaska by Stephen R. Braund. 1988. University of Washington Press, Seattle WA 98145. 144 pp. $19.95.

The Thousand Dollar Yacht by Anthony Bailey. 1988. International Marine Publishing Company, Camden, ME 04843. 214 pp. + xv. $9.95.

Whales

Jacques Cousteau—Whales by Jacques-Yves Cousteau and Yves Paccalet. 1988. Harry N. Abrams, New York, NY 10011. 280 pp. $49.00.

Small-Type Coastal Whaling in Japan edited by Milton M. R. Freeman. 1988. Boreal Institute for Northern Studies and Japan Social Sciences Association of Canada, Edmonton, Alberta T6G 2E9. 120 pp. $20.00.

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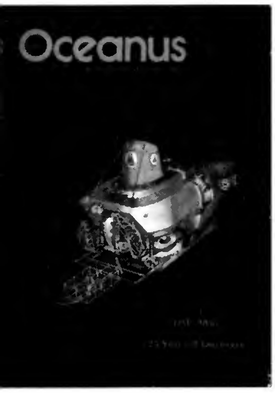

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